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STRENGTH OF EDMONTON SCHOOL CHILDREN

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled

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ABSTRACT

The basic purpose of the study was to discover the status of strength of the major areas of the body, in a sample of Edmonton school children. Both sexes, aged seven to fifteen years were studied. A stringent sampling technique was used in order to assure as random a sample as possible. The basic equipment used for the study included a strength machine which used the Clarke's (21) Cable tensionmeter method. As well a Smedley Adjustable Grip Dynamometer was used. The purpose of the strength machine was to provide body stability and as nearly objective and identical testing conditions as possible. The tests included grip strength, elbow flexion and extension (right and left), knee extension (right and left), and back lift strength.

The reliabilities for testing were found to be very high. Female strength gained slowly until age ten when a rapid mean strength increase occurred for two years. Fourteen year old girls gained little and in most cases lost over thirteen year old girls. Male strength gained slowly and steadily until age twelve when a one-year level-off period was followed by rapid and large strength increments over previous sample groups. Male strength was almost always ahead of female strength - including the younger sample ages of eight and nine. The analysis of results included percentile norms for all of the strength, age, height, and weight. Comparisons made with other reported studies showed that girls compared well, whereas boys did not compare as well. The study established basic standards as well as sex and age differences. A foundation for a longitudinal study has been established.

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"That which is held back is lost forever"

Author Unknown

The character training given me during the last twelve months is surely a memorable experience, when viewed in retrospect. Through thick and thin, through discouragement and encouragement, one carries on. A significant plausible goal makes the task worthwhile. I would like to offer my sincere appreciation to Dr. Max Howell, my Supervisor, Dr. Metro Gulutsan and Dr. Richard Alderman, my committee members. I would also like to thank Dr. Pat Austin and Dr. Maury Van Vliet for encouragement and advice. To Denis Loiselle, my testing counterpart, my most sincere thanks for your hours of testing, your advice and criticism. To Bob Norman, many thanks for your advice and straight forward questions. To the University Works Department and Asao in particular, my thanks for the superb construction of the Strength Machine. Finally, to the Canadian Government, Department of National Health and Welfare, for financial support, to the Edmonton School Boards, and the test school's principals, and to Mr. McCormick of the Dominion Bureau of Statistics (Edmonton), my special thanks.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Leaders in the field of Physical Education have often reiterated that the development of strength is one of the basic, yet major objectives of sound physical education programs (7,24,50). Logically, therefore, one would expect an adequate amount of knowledge available in the field of strength and strength characteristics. The basic muscle groups of the human body have been tested in a number of different ways, and by a number of researchers and medical investigations around the world (1,7,15, 39). Little basic knowledge of the Canadian child, adolescent and adult strength characteristics can be found in the literature. It is evident that strength is to a great extent determined by both sex and age, and that large individual variability is present in this parameter (42). Both cross-sectional (30) and longitudinal investigations (42) have been completed in the area of strength assessment. Many studies have measured strength developed by isometric or static contractions, rather than maximum strength developed by dynamic or isotonic contrations. Grip strength studies are more frequent than studies investigating either back strength, arm strength, or leg strength.

Jones' (42) California Adolescent Growth Study is prominent in the field of strength assessment. The California Study investigated twenty separate fields of child development. One of the fields was Physical Ability Tests. Jones (44:564) described their Physical Ability Tests as follows:

> Dynamometer strength tests (grip, pull, thrust) have been given at six month intervals since the spring of 1932. Beginning in Grade 8, a series

> of tests of bodily control and postural adjustment was added, and also track tests involving speed, power, or accuracy in gross muscular functions.

The California Study was initiated with the following policies and procedures (44:561):

1) From a sample, drawn originally from six schools, covering a wide socio-economic status.

2) The collection of quantitative, comparable measurements for each case in the sample, beginning in the last year of elementary school and continuing through senior high school.

3) Detailed examination of age changes in the various aspects of development, by analysis of individual growth curves, as well as through the study of group changes.

The general pattern of strength growth in the Oakland sample measured by the California Study (43:1) was indicated as follows:

> During later childhood and adolescence strength develops at a more rapid rate than any conspicuous aspect of physique; thus approximately four-fifth of an adult's strength but hardly more than one-third of his height is acquired after the age of six years.

Bookwalter (7:250) has analyzed grip strength by age for over three thousand boys from five states. He found that left grip strength tended generally to increase with age, and that while the progression was slight between ages nine and fourteen, it accelerated from fourteen to seventeen, with the greatest increases at sixteen and seventeen years. The left grip progression showed slightly more irregularity than the right grip. In 1881 the British investigator Galton (33) measured thousands of subjects on height, weight, chest girth, and arm strength.

He stated:

> 1) It was concluded that the strength of males increased rapidly from twelve to nineteen years, and at a rate similar to that of weight; more slowly and regularly up to thirty years, after which it declines at an increasing rate to the age of sixty years.
>
> 2) The strength of females was found to increase at a more uniform rate from nine to nineteen years, more slowly to thirty, after which it falls off in a manner similar to that of males.

Problem

It is the purpose of this study to investigate the status of basic muscular strength(s) occurring in a random sample of seven to fifteen years old boys and girls, and to provide percentile norms of basic strength.

Subsidiary Problems

The subsidiary problems of this study are to investigate:

1) The relationship between height and strength among boys and girls ages seven to fifteen years old.

2) The relationship between weight and strength among boys and girls ages seven to fifteen years old.

3) The relationship between mean right and left grip strength.

4) The interrelationships of all strength variables measured.

5) The relationship between Edmonton childrens' strength and that of other studies.

6) The reliability of ten strength tests

Limitations

The investigation will limit itself as follows:

1) Only subjects who are registered pupils in either the

Edmonton Public School Board system, or the Edmonton Separate School Board system between the ages of five and fifteen years old will make up the population. Age will be taken as that of the date of testing.

2) The following tests will be used in the assessment of strength, and will be given in the following order:

(2.1) right grip strength
(2.2) left grip strength
(2.3) right elbow flexion
(2.4) left elbow flexion
(2.5) right arm extension
(2.6) left arm extension
(2.7) right leg extension
(2.8) left leg extension
(2.9) leg lift
(2.10)back lift

3) Testing will be limited to June 15/1965 to February/1966.

4) The investigation will limit itself to a random sample of one and one-quarter percent of the population, which will result in a sample group of usually 36 boys and 39 girls of each age level studied. The total sample will therefore be comprised of 675 subjects plus reserves.

5) Subjects will not be tested if a school nurse or administrator restricts the subject due to physical handicap or sickness.

Hypotheses

In the problem the null hypothesis asserts that the mean of age group strengths investigated will differ only through fluctuations of sampling during the testing period.

Alternate Hypothesis

The alternate hypothesis asserts that the means of the age group strengths investigated will differ during the testing period.

Definition of Terms

1) Strength. The capacity of a subject to apply a recordable

force to an instrument, through the use of an isometric contraction developed by one or more muscle groups of the body.

2) Population. The total pupils enrolled in the Edmonton Public School Board system and the Edmonton Separate School Board system between the ages of seven and fifteen, during the period September 1,1964 to October 31,1965.

3) Sample. A group of subjects picked in a random manner from a group of schools also picked in a random manner, from the population.

4) Age Group. A sample group consisting of one sex and limited to one specific chronological year of age. All ages are as of date of testing.

5) Sex Group. Either all male subjects or all female subjects per age group.

CHAPTER II

REVIEW OF THE LITERATURE

1. Introduction

Pertinent studies ascertaining the level of strength in human beings go back to the year 1881. Galton (33), in that year, made his report of the Anthropometric Committee to the British Association for the Advancement of Science. Up until 1930 very few studies were undertaken that resulted in objective reporting of bodily strength scores. After that time studies tended to become more numerous and more objective, as succeeding years passed. Since 1946 investigators appear to have become more and more interested in the study of sex and chronological age strength variability. It is the purpose of the present review of the literature to report on all of the above outlined studies. The review will be organized in the following manner. Section I will be devoted to investigations reported up to 1945; Section II to investigations reported between 1946 and the present. This review will therefore be organized according to the chronological method. Dates of publication will be assumed to be relatively synonomous with dates of actual investigation. Exceptions to the above state of affairs will be noted.

2. Strength Investigations Reported Until 1945

In 1930 an American Committee on Growth and Development (21) reported on the increase in muscular bulk in male and female subjects. They reported that in postnatal life the skeletal muscle weight was the following. The newborn male and female have a total skeletal weight ranging between 625 and 732 grams. The six year old female has a skeletal muscle weight of 3,638 grams, while the eight year old male has a weight 4,359 grams. At fifteen years the male has 9,784 grams of skeletal muscle, while at sixteen

he reached a reported 15,722 grams. Figures for two females reported by Ann Roe, of the cited Committee, at age 21 - 22 years were 20,843 grams. The committee (21:67) also reported the following:

(1) The gain in musculature in childhood and adolescence is about equal to the growth of all other organs, systems and tissues combined.

(2) There is no characteristic rate or style of muscular growth. For example the gain in various muscle groups varies from five to fortyfold between birth and maturity.

(3) In general the muscles of the lower extremity make the largest relative gain, those of the upper extremity come next, those of the trunk next, and those of the head make the smallest relative increment.

The White House Conference on Child Health and Protection (72) was reported during 1933. Certain findings of this Conference were similar to those reported by the Committee on Growth and Development (21). MacCallum (72:19) reported the number of fibres in cross sections of a straight grained muscle to be about the same in an adult as in a fetus of six months. Consequently MacCallum pointed out that we must think of the great gain in muscular tissue of infancy and childhood as essentially the result of hypertrophy. The Conference summarized growth of muscle (72:20) as follows:

> Judging from the scattered data available the postnatal growth in muscle is somewhat similar to the growth of the body as a whole; rapid in infancy and childhood, slower but regular in middle childhood, and more rapid again just before and during adolescence. The weight of the voluntary muscle of the well developed male adult of medium stature is usually somewhat over 28 kilograms (over 60 pounds). In adult females of usual build it is somewhat less. Placing these figures in relative form, the skeletal musculature forms about one-sixth of the body weight in the middle of prenatal life, one-fifth to one-fourth at birth, one-third in early adolescence, and about two-fifths (more in men) in early maturity.

That individual muscle groups increase in weight at various rates was noted by the Conference (72:22). Illustrative figures from Table 5 (72:22) indicate the following. The upper extremity muscle weight, in terms of the newborn male weight taken as 1.0, is 4.7 for females at six years, 12.4 for males at fifteen years and 15.9 for females at twenty years. In contrast, the lower extremity equals 6.1 at six years for females, 18.5 for males at fifteen years, and 23.7 for females at twenty years (again taking 1.0 as the weight of the lower extremity at birth for the male). Table 5 was based on data of Theile (1884) using an unweighted average of four females and eight males. The facial and mandibular muscle gains were much smaller than the gains reported above for the upper and lower extremities.

In 1937 Shuttleworth (61) reported on investigations of sexual maturation and the physical growth of girls and boys age six to nineteen. He made a further report in 1939. For height gain in centimeters per year girls exhibited a sharp spurt between 10.5 and twelve years of age, reaching a peak velocity of some eight centimeters per year between twelve and 12.5 years. After this one-half year level-off a sharp drop occurred. For boys, Shuttleworth's data showed that a sharp increase in height occurred between thirteen and fourteen years of age. A level off at the peak velocity of nine centimeters per year occurred between fourteen and 14.5 years, followed by a sharp decline. Investigators in the area of strength growth often compare growth in strength to growth in height. Thus, while Shuttleworth's investigation did not study strength growth he provided data on height, which is beneficial to the present review from a comparative point of view.

The first reference to the California Adolescent Growth Study by Jones (44) was made in 1938. The final reference (43) to this longitudinal study was not until 1949, when a report of the results and conclusions was made.

Policies and procedures of the California Study (44:561) included the following:

1. From a sample, drawn originally from six schools, covering a wide socio-economic status.

2. The collection of quantitative, comparable measurments for each case in the sample, beginning in the last year of elementary school and continuing through senior high school.

3. Detailed examination of age changes in the various aspects of development, by analysis of individual growth curves, as well as through the study of group changes.

In most measurements an interval of six months between subsequent scores occurred. The sample size at initiation of the study in December 1937 was 215 boys and girls, one half of each sex. The physical ability tests provided strength growth scores. A dynamometer strength test consisting of grip, push, and pull was used.

Stuart and Dwinell (64) reported on the growth of muscular tissue as revealed by roentgenograms in 1942. Evaluation of the relative amounts of three principal tissues of the body was done by X-ray. The three tissues differentiated by film shadow densities were (1) cutaneous-subcutaneous, (2) muscle and (3) bone. The method used was applicable to age three months to seven years, and it was indicated (64:195) that by making certain changes in the technique investigation could be carried out on children over six or seven years of age. For boys ranging in age from six to ten years and for example sizes ranging from 25 to 73, the 50th percentiles refer to the area of shadows of muscles in square centimeters. For a similar age range and sample size of girls the percentiles reported by Stuart and Dwinell were 55.0 for six years, 62.2 for seven years, 66.9

for eight years, 70.0 for nine years, and 72.5 for ten years of age. Statistics of significance for sex differences were not included.

In 1944 the Brush Foundation Study of Child Growth and Development was reported by Simmons (62). Seventeen assessments were made on a sample group of 1000 white children. None of the assessments of this noted study was in connection with strength or strength growth.

Breckenridge and Vincent authored a book entitled Child Development (9) in 1944. A limited number of comments and facts pertaining to strength development appeared. Concerning muscle weight (9:254) they stated:

> Muscles increase in weight about 40 times from birth to maturity. During infancy and preschool years, they grow in proportion to the increase in body weight but, between five and six years muscles have a tremendous spurt in growth. In that year 75% of the weight gain is due to increase in muscle. After six years the growth is more gradual. By twelve years, the muscles represent 40 to 45 percent of the body weight, which is the same as that of an adult. (cited in 38). The school years therefore, constitute a period of rapid muscle growth.

A succinct statement of knowledge of muscular strength and the study thereof was made (9:255) by Breckenridge and Vincent:

> The knowledge of the development of the muscular system is still limited. Progress in research in this field has been very slow, since considerable difficulty is involved in finding satisfactory techniques for studying changes in the muscles with growth. Measuring function by the use of tests for motor skills and muscular strength has been done, but this procedure is subject to difficulties. These tests are difficult to apply at any age and especially with children under six or eight years of age, since learning and cooperation are both involved. Also, the effort put into the test varies greatly with the individual.

3. Strength Investigations Reported Between 1946 and the Present Time.

In 1946 Reynolds (57) reported on an investigation into sexual maturation

and the growth of muscle in girls. Reynolds found that at 7.5 years of age girls had about 45 millimeters breadth of muscle shadow, as found by the X-ray method. There was little difference within the female sex of the sample among early and late maturers. At age eight a difference of two millimeters was found, and by age twelve this difference had increased to ten millimeters. Data was reported for the calf muscle only, for ages 7.5 to 12.5 years.

Stuart and Meredith (66:1365) used the measurement of calf circumference to represent muscular development. They presented percentile standards for boys and girls aged five to eighteen. Subjects were Iowa school children of the professional and managerial classes. They were measured between 1930 and 1945. The data was presented as combined results for boys and girls. At age six the 50th percentile was equal to 23.5 centimeters, 25.5 centimeters at age eight, 27.5 centimeters at age ten, 29.5 centimeters at age twelve, 32 centimeters at age fourteen, 34 centimeters at age sixteen, and 34.5 centimeters at age eighteen. At the age of twelve years the 90th percentile for calf circumference was 33 centimeters while the 10th percentile was 26.5 centimeters.

An investigation into the development of motor coordination in boys and girls was reported by Espenschade (27) in 1947. The Brace test was used to measure various aspects of physical ability including agility, balance, flexibility, strength, and control. The stunts of the Brace used to draw out strength aspects were the sit-up from the supine lying position and the push-up from the front leaning rest position. These called upon concentric muscle actions of which speed was not a factor. Espenschade used longitudinal data of the California Adolescent Growth Study as well as a group of 610 subjects measured cross-sectionally. The cross-sectional subjects included

285 boys aged 10.5 to 15.5 years and 325 girls aged 10.5 to 16.00 years. The subjects were tested between 1943 and 1945, in the Oakland area. A criterion pass score was used rather than an absolute measure of strength. Several results were found, the most important of which were as follows:

> 1. The marked improvement of the adolescent boys in all events cannot be attributed to specific practise since both the cross-sectional and the longitudinal groups showed similar levels of performance and rates of change. It reflects, rather, an increased capacity to perform resulting from growth and development in strength and neuromuscular control. (27:39)
>
> 2. The most striking sex difference at all ages is in test 5 (push-up). Here the boys are superior throughout. It is interesting to note that a similar striking sex difference exists in another type of performance which depends also upon arm and shoulder girdle coordination, the distance throw. (27:41)
>
> 3. Boys show an increase in ability to perform events of all classes. The rate of growth is greater after 14 years of age than before and appears to be more rapid in "agility" than in "control". (27:42)
>
> 4. There are only slight sex differences in total scores or in measures of the various classes before the age of 13.8 years. After this time, boys excel in all events and their superiority increases rapidly at each successive age level. (27:42)

Jones (39) reported an investigation into the sexual maturing of girls as related to growth in strength in 1947. Subjects were divided into three groups; the early maturing group whose menarche occurred before twelve years and whose mean age was 11.7 years; the average group whose menarche occurred between 12.5 and 13.5 years and whose mean age was 13.2 years; and the late maturing group whose menarche occurred at fourteen and whose mean age was 14.6 years. Strength test items included right grip, left grip, pulling strength, and thrusting strength. Longitudinal rather than cross-sectional

records were used. A strength composite of the above four strength tests was reported. For right grip strength the three groups (early, average and late maturers) all scored a mean strength of 22 kilograms at eleven years of age. At age thirteen the late maturers scored 25 kilograms mean grip strength, while the average maturers scored 29 kilograms and the early maturers scored 32 kilograms. The average maturers surpassed the early group at 13.5 years and stayed ahead of them over the rest of the ages studied. At thirteen years there was found a statistically significant difference between early and late maturers, at the .01 level of confidence. At fourteen years the difference was in the range of five to six kilograms but was not a statistically significant difference. Standard score calculations for right grip strength for girls revealed a recession phase previous to the pubertal growth spurt in both the early and late maturing groups. Jones (39:136) calculated a total strength score based on a composite of grip strength and pulling and thrusting strength. A comparison of pre- and post-menarcheal cases was made. Calculated at six month intervals of age starting at 12.25 years the pre-menarcheal mean total strength was 86.0 kilograms at 12.25 years (N=63) while at 14.25 years (N=17) it had increased to 100.7 kilograms. For the post-menarcheal group the mean total strength at 12.25 years (N=15) was 100.6 kilograms, while at 14.25 years (N=63) the mean total strength was 107.9 kilograms. The calculated t scores were 3.11, 3.31, 3.68, 2.00, and 1.42 for the mean total strength group scores at 12.25 years, 12.75 years, 13.25 years, 13.75 years, and 14.25 years respectively. A t score of 2.75 was above the level required for significance at the .01 level of confidence. Some of the results (39:143) that Jones reported were the following:

1. Post menarcheal girls are stronger than pre-menarcheal girls of the same age.

2. Strength appears to be more closely related to physiological age than to chronological age.

3. There tends to be support of the hypothesis that endocrine factors which promote early pubertal growth in girls also lead to an early arrest in growth.

4. The early and late maturing reach similar growth levels in later adolescence, but through different patterns of growth.

The measurement of strength of muscle relative to the cross section was reported by Morris (53) in 1948. She carried out her investigation on 24 subjects, one half of whom were males, and all of whom were students at the State University of Iowa. The method was to measure the cross-sectional area by X-ray, and test strength by the use of a hand dynamometer push-pull apparatus, for performing the Martin's break test. This involved use of an isometric contraction. The right flexors and extensors of the arms were tested at 90 degrees, and the right flexors and extensors of the legs at 90 degrees also. The tests were carried on for three days. Morris found (53:303) that:

1. For a group of college students the unweighted average of muscle strength was slightly above 9.2 kilograms per centimeter squared for men and 7.1 kilograms per centimeter squared for women.

2. The results of this research would indicate that with equal muscle cross section and leverage women possess roughly only 78 percent of the muscular strength of men.

Jones (43) made a rather extensive report on the California Adolescent Growth Study in 1949. The majority of the report was contained in the book <u>Motor Performance and Growth</u>. Static dynamometric strength was tested

by use of a grip test, a push test, and a pull test.

Subjects. The subjects ranged in age from eleven to eighteen years, and were all residents of Oakland, California. The subjects were tested longitudinally, the first such study applied to strength. A group of 93 boys and 90 girls was followed twice yearly for seven years. The original group of 183 subjects decreased to 157 five years later, and decreased further to 139 six and one-half years later. By this time all subjects were seniors in high school.

Social Standing of Subjects' Parents. In general the subjects' parents were excessively concentrated in white collar occupations and as skilled workmen, as compared to the United States as a whole including rural and urban groups (i.e. the sample was dominantly urban). There was an under-representation of semi-skilled and especially of unskilled laborers. The median schooling was 11.0 for the fathers and 10.3 for the mothers. Jones stated (43:4) that:

> The selective bias should not be regarded as of special significance in the present study since it will be shown below (section 2.3) that strength measurements and socio-economic factors are unrelated within our sample.

Procedures. For the test of grip strength the California study used a spring dynamometer (manufactured by I.A. Upham of Boston) of the "Collins" elliptical type. For the push and the pull test the grip dynamometer was inserted in a frame(43:5). Tests were repeated semi-annually. The testing was made competitive in the following manner (43:5):

> Each child entered the examination with a classmate, usually a close acquaintance. A competitive element was involved, in that the strength records made by the two subjects were reported, and could be compared; attention was directed particularly, however, to self

> competition, by showing the child his records made at the previous examinations.

In the grip test the subject was seated on a stool with his feet braced, the forearm was flexed and then extended. The hand was in a position of supination, and no more than five seconds was allowed for a given trial. Jones believed a fatigue effect might be present and therefore limited the measurement to three trials of each variable. In support, Jones (43:6) found "in general, the first trial to be the best" although no statistics of significance were given. The best of three trials was used.

Reliability and Constancy of Measurements. Reliability coefficients based on the best trial versus the average of the other two trials ranged from .932 to .964, with little difference between the various ages. Somewhat lower reliability coefficients were reported (43:9) for 72 boys re-measured after an interval of one week. The retest coefficients after six month intervals ranged from .787 to .904 for right grip strength for boys, and from .668 to .742 for right grip strength for girls. Using the average coefficient method of Kelley (41:10) Jones reported that the coefficients averaged about .8 for boys and about .7 for girls. Jones (43:12) also reported reliability coefficients to be raised by using equal age from menarche rather than chronological age. This reflected the subjects' position in the growth cycle. The mean reliability coefficient based on chronological age for right grip was .71, while on the growth cycle or physiological age basis the mean coefficient was increased to .84.

Factors Related to Strength. Jones found that for 72 boys right grip strength intercorrelated with back lift .59, with leg lift .66, and that back lift and leg lift intercorrelated .67. The correlation (43:20)

between strength and either height or weight was not found to be high. Total strength (grip, pull, and thrust) and height at age fourteen correlated .65. At 17.5 years the correlations were .33 $\pm$ .07 between total strength and height, and .52 $\pm$ .055 between total strength and weight. For the ten boys who were most dominantly mesomorphic and for the ten boys who were most dominantly ectomorphic it was shown that (43:21):

1. Mesomorphs exhibited strength superiority in the first year.

2. There was no tendency for ectomorphs to overtake them.

3. On two functions (grip and thrust) the latter group appears to decline with age.

Concerning factors related to strength Jones (43:28) concluded that:

> Strength is related both to body size (especially to weight) and to the mesomorphic component in body build. Taken alone, weight accounts for only 25 percent of the variance in total strength, but 75 percent of this variance is controlled when the components of body build are included with weight and height in proportions based on a multiple regression equation. In other words, static dynamometric strength is relatively independent of gross body size, but a combination of size and body build provide a fairly adequate representation of the factors determining strength.

Growth in Strength. For growth in mean grip strength, growth curves (43:35) have been employed by Jones. For males mean grip strength at eleven years was 25 kilograms, while for girls the mean grip strength was 21 kilograms. Both of these were for right grip strength. By thirteen years of age the male and female mean grip strength had remained nearly four kilograms apart, although they were growing in magnitude slowly. At thirteen the mean female grip strength slowed slightly

in its growth, but by 14.5 years it gained more rapidly again, through to seventeen years of age. By seventeen it had reached a mean total of 35 kilograms. For male right grip strength after thirteen years a steady rapid climb occurred, continuing through to seventeen years. By seventeen the mean right grip strength was 55 kilograms. Expressing it another way the mean male growth for right grip strength was six kilograms per year, from thirteen through to seventeen years of age. The basic pattern of growth outlined for right grip strength was duplicated nearly exactly for left grip growth. As indicated elsewhere in this review its magnitude was lower. The value of one standard deviation for boys at eleven years was 4.09, and 17.5 years was 7.25 units. A relatively regular increase in standard deviation size occurred as age increased. For girls, one standard deviation was 3.86 units at eleven years and was 5.05 units at 17.5 years. The largest relative gain in mean right grip strength for boys was 9.7 percent between 14.5 and fifteen years of age. For girls the largest mean percent gain was 9.2 percent between 12.0 and 12.5 years of age, for right grip strength. For strength of pull girls gained slowly until thirteen years of age, when their mean pull score was 19.20 kilograms. Between thirteen and fourteen no gain (in fact a loss) in mean strength of pull was recorded. A further rapid increase occurred between fifteen and sixteen years. Boys' mean pull strength surpassed girls after thirteen years of age, and the mean difference got larger and larger, reaching some 23.0 kilograms mean difference by seventeen years of age. Thrust strength followed an approximately identical pattern so that of mean strength of pull in both sexes, with the exception that girls gained relatively little

thrust strength after thirteen years. The boys reached a higher terminal level here than they did for mean strength of pull. A comparison of percent of boys surpassing the mean of girls in the strengths measured, was also made. For boys the ascending curves indicate a rapid increase after age thirteen in the proportion of boys excelling the average girl. For example, by fourteen years of age boys surpassed girls in 65 percent of the means for thrust; 85 percent of the means for pull; and in 85 percent of the means for right grip. By 16.5 years the percent surpassing girls' means had risen to nearly 100 percent. In an analysis of sex comparisons of the three strength variables the sample of boys tested showed a rapid increase of percentage of boys surpassing girls after age thirteen. For girls there was a large drop in percentage excelling boys on the three test variables after age thirteen. After sixteen years of age almost no girls surpassed boys. Regarding the magnitude of growth change Jones (43:42) calculated changes in standard deviation units after age eleven, taking age eleven as zero. The total change in gripping strength from age eleven to 17.5 was about twice as great in boys as in girls. For pulling and thrusting the change was about four times as great. Jones noted that these changes were high in comparison with changes such as fine motor abilities, mechanical ability scores and intelligence scores. The total standard deviation change in boys amounted to seven units.

Growth Patterns. The growth patterns constructed from the data collected by Jones showed that previous to age thirteen the pattern for boys and girls was nearly the same. After thirteen, there was a slower rate for girls and a more rapid rate for boys. Jones depicts the different timing

of growth of boys and girls. The following points are significant. At thirteen or shortly thereafter the increment curves for boys and girls on grip strength intersect, and (43:46)

> the girls exhibit diminishing gains at this time, while the boys enter a period of approximately two years of large increments.

In each function girls show a period of secondary increase falling about three years after the principal peak of growth. For pull and thrust the boys' average percentage of growth manifests a characteristic slowing between 12.5 and thirteen years, followed by a spurt to a period of maximal increments. In the four strength functions the growth spurt reaches similar levels at its maximum, which is a rate of growth in one six month period of ten percent in gripping and thrusting, and twelve percent in pulling strength. It should be noted however that the adolescent period of large increments lasts longer in pulling and thrusting. Jones (43:47) also reported upon growth curves in terms of terminal status or the so-called type IV curves. These curves demonstrated that by the age of twelve boys have reached about one half of the grip strength they will show at 17.5 years, whereas the comparable maturity level for pull and thrust is not reached until a year and one half later. Regarding within subject comparability Jones (43:47-48) stated:

> It may be noted that within each sex the relative pattern of growth for right and left grip is substantially the same - so nearly similar, in fact, that separate curves cannot be drawn. This is true even though the right hand is used more than the left and is stronger in absolute values.

Jones (43:48) reported as follows in regard to percentage of terminal

status and its variability:

> Very marked differences appear at age 13 when boys have reached about 45 percent of their terminal strength, both in pull and thrust, while girls have reached about 75 percent of their terminal strength in pull and over 90 percent in thrusting strength.

There also are changes in calculated variability occurring with age. The coefficient of variability is the standard deviation for any given year in percentage of the mean strength score for that year. For girls the obtained standard deviations increase sharply in the period eleven to thirteen years as do the mean scores.

> Among boys the greatest increases in score increments and also in variability, tend to occur somewhat later, i.e. after the age of 13.

For coefficients of variation for grip strength in boys, males show a diminished coefficient of variation at age twelve, an increase to age fourteen, and a subsequent rapid decrease. Among girls a greater differentiation occurs in the several aspects of strength.

Strength and Physiological Maturing. Jones has pointed out (43:53) in regards to longitudinal studies that:

> Longitudinal studies, however, have provided a convincing demonstration that both in physical and psychological measures a growth curve based upon group average may fail to indicate the nature and variety of individual growth patterns.

Exemplary cases have been noted such as a group of three boys who were one standard deviation above the mean initially, and one group of three one standard deviation below the mean ($\bar{x} = 50$) initially, and with minor variations (43:53) each individual maintains approximately his position relative to his chronological age group. On the other hand for two groups of three who started at exactly the same relatively strength level, it

was found that (43:54) the strength score recorded at eleven years did not provide a very good indication of later position. By calculating standard scale units for early and late maturing boys (determined skeletally) it was found (43:59) that:

> . . . . convex-concave form of curves for early and late maturing cases provides a clear representation of contrasting growth patterns. We note (among the early maturing) an upward trend in relative growth rate from 13 to 14 years, with a peak at 14. The late maturing, however, show a decline, relative to the average between the ages of 12 and 15; this is followed by a growth spurt, with a return toward the average after 15. At the beginning and again at the end of the adolescent period, the early and late maturing boys are separated by one standard deviation, but in the middle of the period, when the former has received the full benefit of their earlier growth impetus, the difference between the two groups becomes as great as two standard deviations, and can hardly fail to find representation in the traits related to strength.

For girls it was found that early and late maturers (skeletally) have about the same relationship to the average of the group as do boys. In addition though, it was evident that early maturing girls fail to maintain the superiority (over other girls) reached at thirteen years. The difference between the early and late maturing was significant at the .01 level of confidence (t 2.75 with 30 degrees of freedom). In later years of adolescence their scores tend to drop below the average, although not to a statistically significant degree. Jones indicated an important sex difference (43:63) at this point stating:

> Physical precocity in girls appears to be associated with an early arrest in growth, the same is not true of boys.

Jones (43:64) reported a barely significant correlation of strength with chronological age, at the five percent level of confidence. Finally, in

regard to strength and physiological maturing there has been some controversy regarding the possible diminished motivation of girls in adolescence, to perform measures of maximal physical strength.

Jones noted that (43:64):

> A careful study of individual records fails to reveal evidence of this, although it is probably true that in later adolescence girls are, in general less readily motivated than boys in physical activity tests.

<u>Comparison with Normative Data from Other Studies</u>. In general it was found that the appearance of other grip strength growth curves was similar but there were large differences in absolute level. There was a similar divergence of boys and girls in grip strength after thirteen years of age.

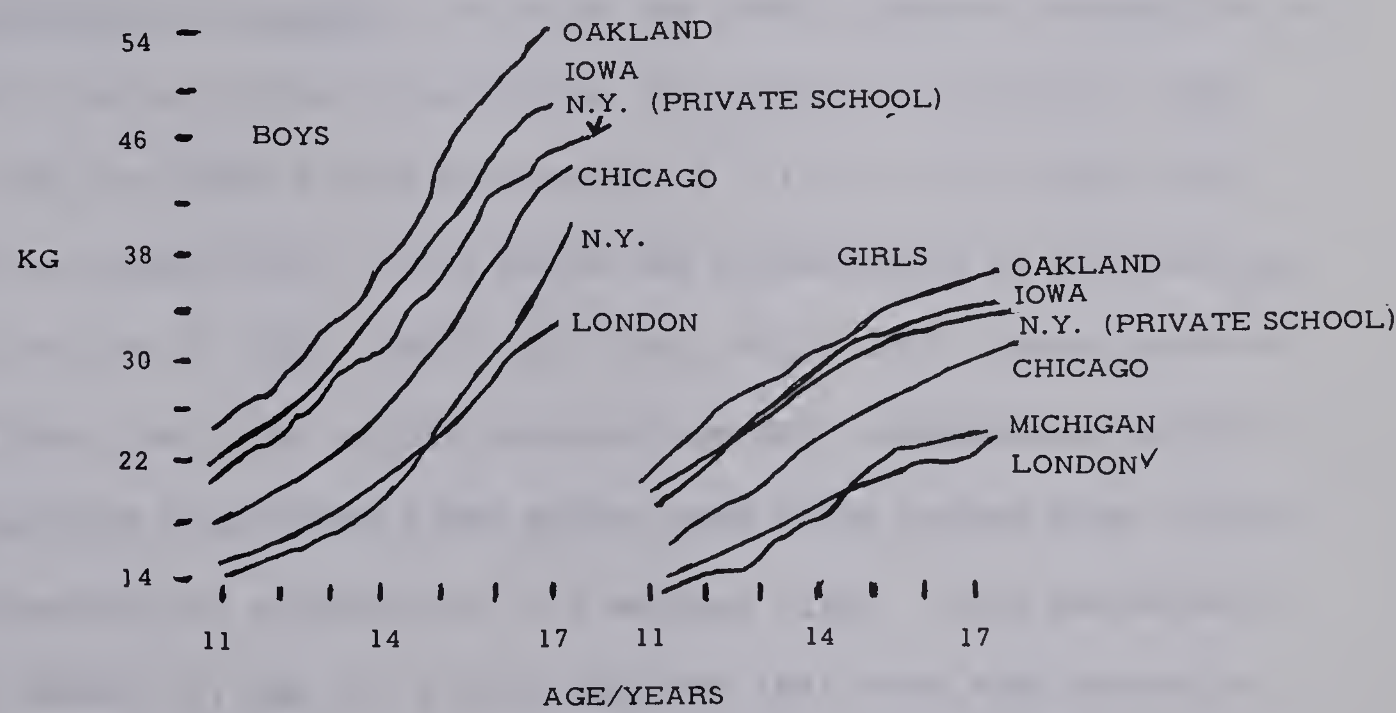

FIGURE I REGIONAL COMPARISONS (GRIP STRENGTH)

(41:99, FIGURE 45)

Comments on Figure 45 from Jones noted the following points (43:99). The poorest performance is the London group which does not meet the Oakland eleven year level until fifteen years. The New York public school group is not superior to the London group during the early years but shows a greater growth after sixteen years. Somewhat similar differences were found for the girls where, for example, at twelve years the Oakland girls surpass the London and Michigan averages obtained at 17.5 years; and at fifteen they surpass the Iowa and New York private school norms for seventeen year olds. Jones notes (43) some difficulties in making valid inferences from such comparisons, such as: (1) test administration differences, (2) scoring differences, (3) motivation differences, (4) instrument differences, and (5) timing differences in data collection where, for example, some data was collected in 1884, some in 1900 and the rest later.

Dextrality in Strength. For males the coefficients of dextrality or the right grip left grip correlations, were found to be .834 ± .026, .780 ± .032, and .868 ± .022 for ages 11.5 - 11.9, 13.5 - 13.9, and 15.0 - 15.4 respectively. For females the correlations at the same age levels were .806 ± .029, .780 ± .030, and .814 ± .027. Jones reported (43:103) that the right - left correlations fall considerably below the reliability coefficients for either hand which ranged from .915 to .959. Corrected for attenuation, the maximal right - left correlation does not exceed .9, and it is thus apparent that even with errors of measurement eliminated, not more than about 80 percent of the variance can be accounted for in terms of the scores for the other hand. In the

Oakland series of experiments the right grip was superior to the left grip in the age range 11.5 years to 16.5 years. The difference in boys ranged between .33 and .44 standard deviation units and for girls between .51 and .61 units.

Bookwalter (7) reported on an investigation of the grip strength of males in 1950. The investigation analyzed male grip strength by age, by weight classes, and by classification indices. The measurements were taken by several authors at different times in Colorado, Illinois, Missouri, Kentucky, and Indiana. Age group sizes ranged from 35 nine year olds to a fourteen year old group of 523. All age groups were measured once. The total sample group was 3,250. No mention was made of the type of testing apparatus used.

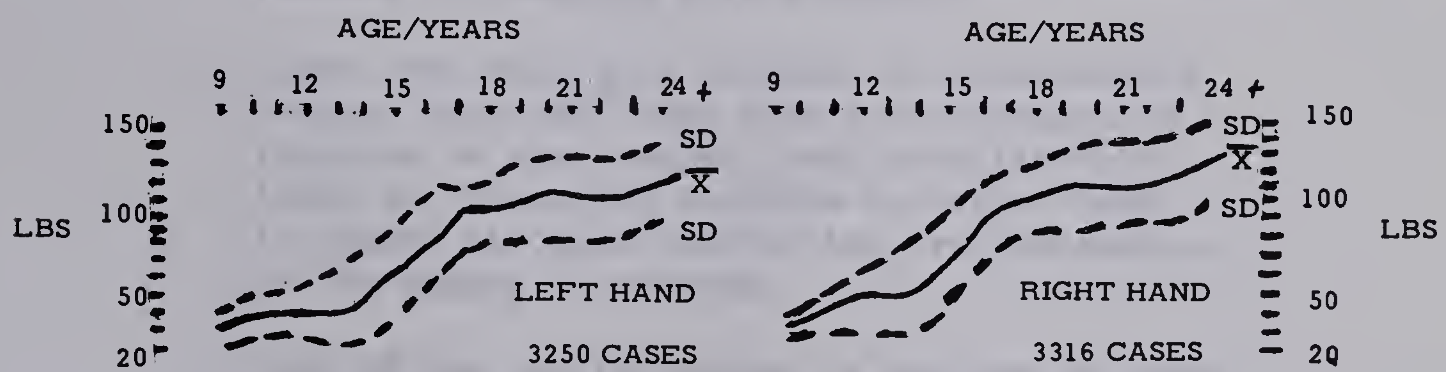

FIGURE II GRIP PROFILES - MALES

(7:250)

The profile reveals that there tends to be an increase in grip strength with age. There is slight progression from nine to fourteen years and

accelerated progression between fourteen and seventeen with the greatest increases at sixteen and seventeen years. A few small irregularities occur between seventeen and twenty-four years and up, but a plateau starts at approximately seventeen years of age. The nine year olds have the smallest grip strength (42 pounds) and the oldest men have the greatest mean grip strength (121 pounds). The left grip strength by age showed more irregularity and range of variability than did the right grip strength. The greatest variability occurred within the fourteen to seventeen year range of mean strength acceleration. Right mean grip strength was greater than left mean grip strength for every age group. Some of the conclusions that Bookwalter (7:273) reported were the following:

1. Age, weight, and classification index I are all factors influencing grip strength.

2. Right hand mean grip strength is consistently greater than left hand mean grip strength in relation to age, weight, and classification index I. This might indicate the right hand is always stronger however the true handedness of the sample in unknown.

3. Each of the profile curves is similar in shape, starting with slow progression of mean grip strength, increased acceleration, and finally less rapid acceleration.

4. Each of the profile curves is similar in variability, starting with slight variability, followed by a period of increased variability, then followed by fairly equal variability throughout the remainder of the curve.

Cullumbine reported on the influence of age, sex, physique, and muscular development on physical fitness (23) in 1950. Three parameters of fitness were investigated, including static fitness, functional or strenuous work fitness, and specialized fitness. Many tests were given

including right grip dynamometric strength to assess static fitness. The subject group comprised 7,000 Ceylonese subjects age ten and over. The majority of the subjects were male and female school pupils, aged ten to twenty, while some of the sample group, over thirty years of age, were in other occupations. Means, standard deviations or other statistics for grip strength were not included in the report. They found (23:503) an increase in intensity of grip strength from age ten onward. At all ages female grip strength was less than males. They indicated that the increase in mean female grip strength paralleled that occurring in males in pre-adolescent years. The rate of increase in females became much slower after fourteen years of age.

Lombard (48) investigated the breadth of bone and muscle by age and sex in childhood during 1950. The study was a further attempt to analyze body weight into its component factors of muscle, bone, and fat, by use of anterior-posterior roentgenograms of the calf muscle. The subjects were described as boys and girls aged six to sixteen, with no further description given. The sample group size per age ranged from twenty-five to eighty-one for the boys, and fourteen to seventy-six for the girls, with a mean sample number of forty. The rate of increase in the mean breadth of bone and muscle was reported by sex and age by Lombard (48:230). For boys, at six foot X-ray distance, the age six to seven mean increase was 3.3 percent; for the age groups seven to eight, nine to ten, ten to eleven, and eleven to twelve the mean percentage increase ranged from 3.0 to 5.3; at ages twelve to thirteen, and thirteen to fourteen the mean increase was 5.8 percent; and for age fourteen to fifteen a peak mean

increase of 6.2 percent was reported. The age fifteen to sixteen mean increase dropped to 2.1 percent. For girls the mean percentage increase ranged from 1.6 to 4.3 for the early age groups of ages six to seven, seven to eight, eight to nine and nine to ten. A rise to 5.5 percent at age ten to eleven occurred, and a peak mean increase of 6.6 percent occurred at age eleven to twelve; the mean percentage increase gradually dropped to 3.4 at age fourteen to fifteen and for age fifteen to sixteen a mean negative increase of 1.5 percent occurred. Other findings reported by Lombard (48:231,238) were:

1. Girls appear to have proportionately more subcutaneous tissue and less bone and muscle than boys throughout life.

2. Girls tend to show somewhat more variation through age 10, after which age their variation increases markedly above that for boys. This increase in variation around the mean coincides with the prepubertal growth spurt for girls. By age 14, when the majority of the girls had passed through this period of accelerated growth, the variation had decreased to a point lower than for boys.

Willgoose (73) in 1950 investigated the strength of boys using Rogers' Physical Fitness Inventory, and related strength scores to motor performance skills. He reported results of tests on 875 subjects aged twelve to eighteen years of age. The inventory included grip strength, back and leg strength, chin-ups, push-ups, and a height-weight multiplier. For a group of 75 boys aged thirteen to fifteen the range of scores reported by Willgoose was from under 1400 to over 2200. This score is a composite score. For 500 boys aged twelve to eighteen the range was from under 1000 to over 3000, and for a group of 300 boys aged fifteen to eighteen the range of scores

was from under 1800 to over 3000.

Watson and Lowrey (70) in their book Growth and Development of Children commented upon the timing of the maximal growth of muscle in relation to other indices. They (70:116) stated:

> It can be seen that the maximal growth in muscle mass occurs relatively late and follows chronologically the maximal growth in height. It has been found that strength virtually doubles between 12 and 16 years, but the peak increase tends to follow the major increments of height and weight.

In 1952 Everett and Sills (29) reported on the relationship of grip strength to stature, somatotype components, and anthropometric measurements of the hand. Additional grip strength measurements were made of hand length, hand width, palm length, and finger length. The sample group numbered 400 while age ranged from fourteen to twenty-nine years of whom only six percent were over age twenty. Grip strength was measured with a Narragansett dynamometer. Everett and Sills found a mean grip strength of 113.15 pounds at 17.91 years of age. The zero order correlation between grip strength and age was equal to .4694. They commented (29:165) upon the finding as follows:

> For the subjects who were tested, age had little influence upon grip strength.This fact was emphasized when other variables were held constant and age was correlated with grip strength. In previous studies when samples were taken from younger age groups, higher correlations for grip strength with age were found. We believed that these differences would have been minimized if the same variables had been held constant in each of the studies when grip strength and age were correlated.

Burke, Tuttle, Thompson, Janney, and Weber (11) investigated the re-

lationship of grip strength and grip strength endurance to age. They reported their findings in 1953. The subjects included 311 normal males aged twelve to seventy-nine years. The school age attended school while the others were heterogenous as to occupation. A dynamometer was attached to a strain gauge. The signal was amplified and then recorded by an Esterline-Angus meter. The gauge limited movement to the extent that the authors indicated the contraction to be isometric. The results were reported for dominant side only (11:629) since; ". . . data from the non-dominant hand yielded the same picture, except both maximum grip strength and grip strength endurance were less." For the twelve to fifteen age group (N=97) the mean grip strength was 73 pounds (S.D. = 22); for the sixteen to nineteen age group (N=77) the strength was 99 pounds (S.D. = 15); and for the group age twenty to twenty-four (N=11) the mean strength was 121 pounds (S.D. = 16). At each successive age group investigated the mean strength was slightly less than the former age group. The number of subjects was small in all cases. The standard deviations reported stayed relatively the same as those already referred to. They found a rapid increase in mean grip strength and mean grip strength endurance from twelve to twenty-five years.

Kraus and Hirschland (46) made their report on minimum muscular fitness tests in school children during 1954. They used six basic tests including abdominals plus psoas, abdominals minus psoas, psoas, upper back, lower back, and back and hamstrings. Subjects aged six to sixteen were tested including 4264 Americans and 2870 Europeans. In regard to fitness and age (46:178) they stated:

> The Kendalls reported a very definite variation of results with age (5) and we fully agree with the authors that the ages 10 to 13 years seem to be the "critical" ones. We found, however, that this "critical" period was one or two years earlier in European children.

Phillips (54) analyzed results of the Kraus - Weber tests and carried out grip strength tests by the manuometer method as well. A total of 1456 children from a city of 26,000 were tested, whose age ranged from six to twelve years. The grip strength test was given to a total sample group of 350 subjects. Phillips found a mean grip strength of 45.9 pounds for boys aged six to twelve, and a mean grip strength of 40.8 pounds for girls of the same mean age. This sex difference was statistically significant at the .01 level of confidence. Regarding the relationship found between grip strength scores and Kraus - Weber scores Phillips (54:322) stated:

> No relationship appeared to exist between the Kraus - Weber test and the Grip Strength test. The differences between the mean grip strength of children passing the Kraus - Weber test and those failing this test lacked statistical significance. This was true for both boys and girls, although a significant difference between the boys and girls was found, in favor of the boys.

In 1955 Tanner (67) reported a mass of summarized materials in connection with growth at adolescence. This British book summarized strength growth knowledge in one chapter. The bulk of the work was built around the findings of Jones. Other material was used and appears in the present review under separate sections. Tanner (67:135) made comment upon the layman observation regarding outgrowing one's own strength, stating:

> It is possibly this period elapsing between the achievement of full body size and the

> development of full muscular power that has given rise to the popular notion of a boy "outgrowing his strength". There is no time during adolescence when strength ceases to increase, and it is certainly not true that the changes accompanying adolescence even temporarily enfeeble, through any except a psychological mechanism. But there is it would seem a period of about a year when a boy, having completed his physical growth, does not have the strength of a young adult of the same body size and shape.

Hall (34) reported on a number of strength tests upon 4-H club members in the state of Illinois. One of the tests used was of arm pull. Subjects who were seated with their feet against a bar pulled against a spring scale in a test of back and shoulder muscles. Boys and girls ranging in age from ten years to 19.5 years were tested. The sample was large, involving some 5,000 subjects of each sex. The scores in the arm pull ranged between a mean of 150 pounds for ten year old boys and 326 pounds for 19.5 year olds. The largest increases occurred between ages 13.75 years and 16.25 years for boys. For girls the mean arm pull was 131 pounds at ten years and 194 pounds at 19.5 years. The largest mean increase occurred between 11.25 years and 13.9 years for the female sample.

Rarick and Thompson (55) reported an investigation in 1956 which related roentgenographic measures of leg muscle size to ankle extensor strength measurement. The study used a small sample group (N=32) boys, and 19 girls) of American born whites in grade one at Madison, Wisconsin. The soft tissue roentgenogram method and the Clarke cable tension technique were used. The correlations between ankle extensor strength and the measures of leg muscle size ranged between .58 and .63 for boys and between

.22 and .52 for girls. The boys were substantially stronger than the girls in ankle extensor strength, at the .02 level of confidence. Boys also possessed on the average greater muscle size. Rarick and Thompson found that by pairing boys and girls on the basis of muscle size that the superiority of the boys was significant at only the 30 percent level of confidence. The authors (55:331) concluded:

> While the evidence suggests that qualitative differences in muscle tissue may exist at this age level and that boys have at their command greater muscle power per unit of muscle mass than girls, further investigation is needed before definite conclusions can be drawn.

Buxton (12) investigated results of the Kraus - Weber test as well as tests of strength in other areas of the body, and reported findings in 1957. A leg strength test was used which consisted of a vertical jump with arms folded. The coefficient of reliability for the test was .93. Some 1,057 boys and girls aged six to fifteen were tested, resulting in sample groups of 50 per sex, per age. The subjects resided in the Iowa City, Iowa area. Mean performance scores for leg strength indicated that boys and girls follow a similar pattern of mean leg strength growth until ten years, when girls reach a one year plateau before gaining sharply from eleven to thirteen years, at which time they level off. Buxton found the boys to improve gradually until age thirteen when their scores gained rapidly until age fifteen. Scores were not reported beyond age fifteen. The boys' scores were superior to the girls throughout the ages tested. Only at ages fourteen and fifteen were boys' scores significantly different than girls. The differences were significant at the .01 level of confidence. The differences in mean within both sexes at ages six to fifteen years were

significant at better than the .01 level of confidence.

Hunsicker and Greey (37) reviewed studies in human strength and reported these in 1957. The main results or conclusions of many pertinent studies were noted. By and large these points will be reviewed separately in the present study. The authors listed a number of points themselves (37:118-119) stating:

> 1. There is only a slight difference in the strength of the two sides of the body.
>
> 2. Body type is related to strength and those possessing a high mesomorphic component have the greatest amount of strength.
>
> 3. There is a difference between static and dynamic strength and the relationship between the two is not high.
>
> 4. Four-fifths of an adult's strength but hardly more than one-third of his height is acquired after age six.

In 1959 Bayer and Bayley (6) presented data pertaining to diagnosis of grip strength as well as strength of push and pull. Their data however, was not collected from a random sample of a normal population. They presented data for seventeen to eighteen year old girls who were classified as hyper-masculine, masculine, intermediate, feminine, and hyper-feminine. The reported mean strengths (6:193) were high for the hyper-masculine types and diminished in the same order as the masculine to feminine type change-over noted above. A Collins - type dynamometer was used.

Clarke and Carter (17) reported on Oregon simplifications of strength and physical fitness indices in 1959. All items of the strength index were administered to a sample group of boys. The index items included

right and left grip strength, back lift, leg lift, pull-ups, push-ups, and lung capacity. The tests were carried out in 1956 - 57 upon 356 boys from Medford, Oregon. The age range was nine to seventeen years. The boys were reported to be above normal on the Physical Fitness Inventory. The median PFI score for a random population was 100, while quartile one was equal to 85 and quartile three equal to 115. The results indicated that for age nine to seventeen (combined) the correlation between SI and weight and age was equal to .901. The addition of height to this computation did not increase the reported correlation. Left grip strength and right grip strength intercorrelated in the range of .72 to .87 for three age groups in the total age range studied (elementary group age nine, ten, and eleven; junior age group twelve, thirteen, and fourteen; senior age group fifteen, sixteen, and seventeen). Back lift correlated highest with grip strength at the junior ages (right grip equals .84 and left grip equals .77) and lowest at the elementary ages (r equals .43 and .56). The intercorrelation between leg lift strength and the mean strengths of right grip, left grip, and back lift followed the same pattern as that just reported for mean back lift score. The reliabilities were similar quantitatively.

In 1960 Stuart and Prugh (65) reported upon the healthy child and his physical, as well as psychological and social development. They reported data (65:89) collected for average gains in selected body measurement for boys and girls of ages five to eighteen years. The body measurement was calf circumference measured in centimeters. For boys a gradually increasing gain was found between seven and nine years; followed by a

declining gain between nine and eleven years of age to nearly 0.8 centimeter per year; at twelve years the decline had reversed and the gain had returned to 1.0 centimeters, between twelve and thirteen the gain reached 1.25 centimeters and between thirteen and fourteen years of age a maximum mean increase of 1.5 centimeters per year was reported. After this the gain declined steadily and at seventeen to eighteen years had reached 0.3 centimeters. For girls the pattern was similar but the maximum years of increase occurred earlier. Specifically, the maximum increase of 1.15 centimeters per year occurred between the tenth and twelfth year of age. The suddenness of the spurt was more marked in the girls studied than in the boys studied. The data was based on samples of two white populations in two regions of the United States. Stuart (65:116) has indicated the following aspects of strength growth in the adolescent:

> 1. Finally, the continuing growth of skeletal muscle is an important feature of adolescence. This apparently continues, or may do so, long after growth in height has come to an end, or has become minimal. This is particularly a feature of adolescent growth in boys, and accounts for the greater muscularity of men.
>
> 2. It is during adolescence that marked differences in muscle strength develop between boys and girls. Starting with relatively little difference in pre-pubescent performance, under most tests for strength, this difference becomes very marked in postpubescence.

In an investigation of ages of adolescence and pubescence Stuart and Prugh (65:126) found the onset of pubescence for the average girl to be twelve years and the end to be fourteen years, for the early maturing

girl to be ten years and twelve years (end), and for the late maturing to be fourteen years and sixteen years (end). For boys the average onset of pubescence was fourteen years and the average end was sixteen years. For early maturing boys the onset was twelve years, and for late maturing boys the onset was sixteen years. This data is related to much of the data reported for growth of strength.

Torpey (69) analyzed the leg extension strength of 450 children of grade one to six age in Niskayuna, New York. The results were reported in 1950. Torpey used the Clarke cable tension test of the right leg only. It was found that the means and standard deviations increased steadily with increased grade level. The boys' mean strength was larger than that of the girls throughout, and in most cases their standard deviations were also larger. Statistics of difference between sexes were not reported. The high and low scores indicated that some first grade boys had stronger leg extension than did some sixth grade girls. Grade one mean boys' strength (N=41) was 53 pounds, their standard deviation was fourteen pounds, and their mean scores ranged between 100 pounds and 35 pounds. The girls' mean score was only one pound less. The mean scores between sexes diverged more between grades two to five (three pounds, eight pounds, nine pounds and thirteen pounds). At grade six both mean scores were 95 pounds (N=36 boys, 24 girls).

In 1961 Clarke and Petersen (16) contrasted strength characteristics of athletes and non-athletes ten to fiteen years of age. Three levels of athletic team members were contrasted within themselves, as well as with non-participants. It was found that athletes were significantly greater

in many of these measures.

A comparison of motor performance of adolescent boys and girls of today with those of 24 years ago was reported (26) by Espenschade and Meleney in 1961. Included in the comparison were measures of height and weight as well as grip strength, and push and pull strength. The push and the pull tests were identical to those used in the California Adolescent Study. The original testing was carried out in 1934-35 while the comparative testing was carried out in 1958-59. The original subjects (N=235) were the eight grade sample of the California Study. The comparative sample attended the same school as the 1934-35 group, were all white subjects from Oakland, and were judged (26) to be to a "fairly high degree", similar as to intelligence quotient, socio-economic status, and other characteristics. School population had been doubled, new buildings had been added, and there was in general less room for outdoor recreation. It was reported that the physical education instructor was the same person, but that the program was slightly modified. Espenschade, the senior author, had collected the earlier data and supervised the later collection of the 1958-59 data. Identical measures were used, and the same instruments were used after recalibration. The mean average height of the 1958-59 sample was one inch greater and their weight was six pounds heavier. The differences for boys were over two inches and ten pounds heavier, in favor of the recent sample. In the dynamometric strength measures both boys and girls of the recent sample were superior in the pull. For girls a calculated "t" score of 3.40 was significant at the .01 level of confidence, and for the boys the "t" score was equal to 3.54, also significant. It was found

that present day boys excelled in grip strength, while girls were not significantly different (t= -.45). The "t" score for boys' grip strength comparison equalled 2.82, which was significant at the .01 level of confidence. Boys were not significantly different in the push but girls were. Girls of 1934-35 were superior (t= -2.90). This is a significant difference in favor of the original group, at the .01 level of confidence.

Hettinger (35) has combined views and conclusions of other investigators with results of experimental studies of his own. He reported results in 1961 in his <u>Physiology of Strength</u>. He (35:9) has stated regarding sex differences in strength that:

> There is a relationship between the differences in strength in men and women reflecting the strain of the different muscle groups in daily use.

In further sex comparisons using the mean strength of males as 100 percent, the forearm flexor and extensor mean strength of females was equal to 55 percent of males, and the shank flexor mean strength was equal to 65 percent of that of males. Hettinger found agreement (35:9) when he noted that:

> A review of the literature substantiates the statement that in general muscle strength in women is about 2/3 that of men.

In a graph of results from various sources (35:11) maximum strength was related to age and sex. At age ten boys and girls were increasing steadily in strength and had developed 40 percent of the maximum mean strength of males. Females increased their strength further between ten and fifteen years of age and reached their mean maximum soon after that. The graph showed the female mean maximum to be nearly 58 percent of the male mean maximum. The male increase was sharp and steady until eighteen years of

age when it decreased to a slower pace to the mean maximum at twenty years of age. Hettinger's results indicated a mean difference between sexes of twenty percent at fourteen years of age. This difference became larger and larger as years passed. He (35:12) calculated muscle strength to be about four kilograms per centimeter squared cross-section of muscle, in both males and females. Regarding the high standard deviation of strength in various muscle groups (35:16) Hettinger remarked:

> The strength in the different muscle groups of the body is quite different, and measurements in a great number of people show a very high standard deviation in the same muscle group.

Asmussen and Heeboll-Nielsen (1) have investigated isometric muscle strength in relation to age in males and females. They measured strength in 25 muscle groups. The subjects included 360 males and 250 females chosen at random, aged fifteen to 60 years. All testing was done with strain gauge instruments developed at the Danish Polio Institute. All measurements were made as attempted movements from standard, easily reproducible positions. Measurement values for the different muscle groups were expressed as percentages of the strength of the same muscle group in the 20-22 year old group of men, and then calculated as means. Among results reported by Asmussen and Heeboll-Nielsen (1:168) were the following:

> 1. Isometric muscle strength increases till (sic) the age of 60 years after which a first slow, later somewhat faster decrease in strength takes place.
>
> 2. At age 30 the average strength is 104 per cent of that of the 20-22 year old (male).
>
> 3. For the women (Curve II) isometric strength does not increase appreciably after 20 years of age. At this age it is about 65 percent of that of men.

Asmussen and Heeboll-Nielsen corrected the total strength of females compared to males by comparing them on the basis of equal cross-sectional areas of muscle strength, as follows:

> 4. Corrected in this way, the strength of adult women will be increased to about 77 per cent of that of men. This difference is probably the true sex difference in muscle strength.
>
> 5. When different muscle groups are studied separately it appears that they reach maximum strength and begin to decline corresponding to different ages. There seems to exist a characteristic difference in this respect between the muscles of the hand and upper extremity as opposed to those of the trunk and the lower extremity.

Clarke and Wickens (19) have analyzed the maturity, strength, and motor ability growth curves of boys aged ten to fifteen years. Their results were reported in 1962. The subjects were tested in 1956-57 from a random sample of Medford, Oregon public school boys. About 40 boys at each age were tested, within two months of their respective birthdays. Strength measures included left and right grip strength, back lift, leg lift, pull-ups, push-ups, and arm scores. For nine year olds the mean right grip strength was eighteen kilograms, while the mean left grip strength was seventeen kilograms. A slow and steady increase in mean grip strength of both hands continued until age twelve, to nearly 26 kilograms. At this point both of the mean grip strengths rose sharply until fourteen years of age, when the gain appeared to level off. By age fifteen the mean right grip strength was 44 kilograms while the mean left grip strength was 42 kilograms. Regarding grip strength Clarke and Wickens (19:33) commented:

> 1. The mean right grip strength increased from 17.7 to 44.1 kilograms, a gain of 26.4 kilograms, or 149 per cent. For left grip strength, the means were 16.7 and 41.7 kilograms, at ages 9 and 15 respectively; this difference is 25.0 kilograms, an increase of 150 per cent.

With the exception of the age of twelve years the means for right grip strength were consistently higher than for left grip strength. At age ten this difference was 2.15 kilograms which results in a computed "t" score of 3.10, which is above requirements for significance at the .01 level of confidence. At age thirteen the "t" score is 2.95, also a significant difference (.01 level of confidence). The results of the back and leg lift scores as indicated (19:33,34) by Clarke and Wickens are as follows:

> The mean growth curves for back and leg lifts had the following characteristics in common: a relatively slight increase during ages 9 to 10, a deceleration at 11 years, a pronounced and nearly straight line rise from ages 11 to 14, and some deceleration at the age of 15 years. The mean back lift of the boys at 15 years of age was more than twice as large as at nine years since the means of 148 and 69 kilograms; respectively, represent an increase of 115 per cent. For leg lift, the comparable increase was 175 per cent, since the mean was 175 kilograms at nine years and 482 kilograms at 15 years.

Clarke and Wickens found that standard deviations of the coordinated strength measures generally increased with age. Regarding coefficients of variability they (19:34) found; "As with the structural measures, the relative variability of the coordinated strength measures differed from measure to measure and from age to age." For four measures (back lift, Strength Index, left grip and right grip) the mean coefficient of variation varied within narrow limits ranging from 14.87 to 20.80. The

mean coefficient for leg lift was only slightly higher, equalling 25.33. The other measures were very much higher. Knee flexion mean strength for the age twelve group was 30.7 kilograms, while it was 75.1 kilograms for the fifteen year old group, a gain of 144 percent.

Clarke and Harrison (15) continued to investigate physical characteristics of Medford, Oregon boys as part of the Boys' Growth Project in 1956-57. They attempted to determine if muscular strength and other characteristics differed significantly between boys of advanced, normal, and retarded skeletal maturity. Results were reported in 1962. A random sample of 273 boys aged nine, twelve, and fifteen years was tested. Wrist hand X-ray were used to determine the skeletal maturity levels of the boys. Cable tension strength measures were used. A summary of the "t" ratios for the differences between the means of boys aged nine, twelve, and fifteen years was given. The results and conclusions (15:20) include the following:

1. As for structural measures the highest and most consistent t ratios for the differences in the strength and explosive power means were found between the advanced and retarded maturity groups.

2. The tests with significant differences between the means at all three ages were grip strength, leg lift, Strength Index, mean cable tension strength, and elbow flexion strength.

3. The highest and most consistently significant differences between the means of all experimental variables were obtained when the 15 year old maturity groups were compared. The differences between the means of the 12 year old maturity groups were next, and the 9 year old maturity groups last.

Baacke investigated a number of physical performance measures and related them through correlational techniques to certain motor performances.

He reported (3) his findings in 1964. The subjects were 87 high school students of all classes in Concordia, Missouri. He tested the subjects on leg lift strength. The tensiometer and bar and belt method was used, with the knee angle ranging between 115 and 124 degrees. The height of the subjects ranged from 150 to 188 centimeters, and the weight from 68 to 188 pounds. The mean leg lift strength for the total sample group was 704.149 pounds, and the value of one standard deviation was 184.388 pounds.

Rarick and Oyster (56) studied physical maturity, muscular strength, and motor performance of young school age boys. Their findings were reported in 1964. The subjects were 48 boys in grade II, whose mean age was 100 months (S.D. = 8.2 months). They were from an upper middle class suburban community. Skeletal maturity of the hand and wrist was determined by roentgenograms. Eight measures of cable tension strength were recorded including knee extension and elbow flexion strength. Reliability coefficients of the cable tests was computed on a test-retest basis. For strength data the reliabilities ranged from .68 to .93, with all but three (of 24) computations being better than .75. Zero order correlations for mean knee extension were as follows: .63 with chronological age, .51 with skeletal age, .73 with height, and .67 with weight. Rarick and Oyster commented (56:526) regrading these correlations that:

> It is clear that neither skeletal age nor any other one of the three growth factors accounted for a major part of the variance in any of the strength or motor performance measures.

The investigators used partial correlation techniques to further their

study. For first order correlations with weight held constant knee extension strength correlated .42 with height, .44 with chronological age, and .08 with skeletal age. With height held constant the correlations were .14, .38, and .09 with weight, chronological age, and skeletal age respectively. With chronological age held constant the correlations were .51, .59, and .24 with weight, height, and skeletal age respectively. Finally with skeletal age held constant the resulting correlations were .62, .51, and .48 with height, weight, and skeletal age respectively. The data (56:526) illustrates that:

> . . . by holding chronological age constant, all correlations between the physical growth variables and the respective measures of strength and motor performance were lowered. Similarly the correlations were reduced by separating out skeletal age, height, and weight.

The authors (56:529) concluded that:

> The results of this study clearly demonstrated that readily available measures of physical maturity, such as chronological age, height and weight were of as much significance in accounting for individual differences in strength and motor performance as was skeletal age.

Rosenstein and Frost (58) investigated the physical fitness of thousands of New York state high school pupils, in connection with an evaluation of quality of high school physical education programs. The large sample group consisted of 3,650 girls from grades ten to twelve, and 4,128 boys also of the same grades. The results of the study were reported in 1964. The New York State physical fitness test was given, which included strength measures. The test-retest reliability of the

teachers carrying out the testing was calculated to range between .79 and .98. The growth of fitness scores was indicated by an analysis of covariance. For strength measures a significant difference at the .01 level of confidence was found for mean male strength at each grade level and for mean female strength at each grade level. The female age range was probably between fifteen and eighteen years.

Fleishman (30) investigated fitness test scores for a large American sample and reported the results in 1964. The tests used were given to over 20,000 boys and girls in 45 American cities. The sample group was primarily urban in nature and with only one exception all subjects were from cities of over 25,000 population. A wide geographic area was covered. More middle socio-economic than other groups of the population were included. The age range was from thirteen to eighteen years for both sexes. For the hand grip test the primary factor measured was static strength. The primary factor loading was .72. Test-retest reliability was computed to be .91. A Narragansett hand dynamometer was used for all the hand grip measurements. The preferred hand was tested. The subject took the test while standing. The highest reading of three squeezes was recorded. The results for girls, examining the 50th percentile mean scores (30:53), were as follows:

	P_{50}
Age 13	42 pounds
Age 14	43 pounds
Age 15	55 pounds
Age 16	59 pounds
Age 17	63 pounds
Age 18	67 pounds

The largest difference in the girls' mean scores appeared between age fourteen and fifteen years. The mean differences at all other ages ranges

between one and four pounds. For boys at the 50th percentile the scores were as follows:

	P_{50}
Age 13	65 pounds
Age 14	78 pounds
Age 15	93 pounds
Age 16	106 pounds
Age 17	109 pounds
Age 18	114 pounds

Large mean differences are found between ages thirteen, fourteen, and sixteen years. The mean differences are much smaller between sixteen and eighteen years of age.

SUMMARY OF THE REVIEW OF THE LITERATURE.

Strength Investigations up to 1945. The American Committee on Growth and Development (21) reported upon skeletal muscle quantity at various ages. The gain in musculature in childhood and adolescence was found to be nearly equal to all other organs, tissues, and systems combined.

The first reference to the California Adolescent Growth was made in 1938 by Jones (44).

Stewart and Dwinell (64) reported on the growth of musculature as revealed by roentgenograms in 1942.

Breckenridge and Vincent (9) in 1944 summarized existing knowledge on the growth of muscles and pointed out that a lack of knowledge existed in the field.

Strength Investigations Between 1946 and the Present. Espenschade (27) in 1947 used the push-up from supine lying position and the push-up from front leaning rest position of the Brace test to test strength. Using longitudinal and cross-sectional data she found that only slight sex differences existed before the age of 13.8 years, with boys excelling

after this time.

Jones (39) compared strength measures of girls who varied in sexual maturity. He found post-menarcheal girls to be stronger than pre-menarcheal girls of the same age, and that strength is more closely related to physiological age than to chronological age.

Jones (43) in 1949 made an extensive report on the California Adolescent Growth Study. He found, by using the average coefficient of reliability method of Kelley, that the reliability averaged 0.8 for boys and 0.7 for girls. He reported that for males of age eleven , the mean right grip strength was 25 kilograms (55 pounds), while for girls it was 21 kilograms (45.1 pounds). Until thirteen years of age the sex difference in strength was around four kilograms (8.8 pounds). For males after age thirteen the mean gain in strength decreased, but by age 14.5 years it increased again. With regard to the standard deviation in grip strength a relatively regular increase occurred as age increased. The largest gain in right grip among males occurred between 14.5 years and 15.0 years; and females between 12.0 and 12.5 years. In comparing the Jones data to other studies it was apparent that while the appearance of other grip strength growth curves was similar there were large differences in absolute level. The Oakland grip scores were superior to those in Iowa, New York (private school), Chicago, New York, and London.

Bookwalter (7) reported on male grip strength in 1950. Several investigators in several states carried out the study. Results from a large sample group showed slight progression from nine to fourteen years and accelerated progress in between fourteen and seventeen years. Nine year olds had a mean

grip strength of 42 pounds. He found right grip strength to be consistently greater than left mean grip strength. True handedness of the sample was not known.

Cullumbine and associates (23) measuring a large Ceylonese sample group found that at all ages female grip strength was less than that of males. They found the increase in female grip strength to become much slower than the males, after fourteen years of age.

Phillips (54) administered a grip strength test to a group of boys and girls of the same age, and found the boys to be superior in mean grip strength, the difference being significant at the .01 level of confidence.

Hall (34) found, for a test of arm pull of a large (N=5,000) sample group, that boys at ten had approximately similar scores to girls of the same age, but that by nineteen years of age male mean arm pull was 326 pounds whereas female mean arm pull was 194 pounds. For males the largest increase occurred between ages 13.75 and 16.25 years, and for females the largest mean increase occurred between 11.25 and 13.9 years.

Buxton (12) concluded that both males and females follow a similar pattern of mean leg strength growth until ten years of age when females plateaued for one year then gained sharply, but levelled off after age thirteen. Males gained rapidly between thirteen and fifteen.

Clarke and Carter (17) reported that right and left strength of grip intercorrelated in the range of 0.72 to 0.87 in a male sample aged nine to seventeen. Back lift correlated highest with grip strength (above 0.77 and 0.84) beyond age twelve. Other correlations followed the same pattern.

Torpey (69) reported upon right knee extension scores by the cable tension method and found males to be superior to females at all ages studied, from grade one through to six. Boys' mean strength was 53 pounds at grade one and 95 pounds at grade six.

Hettinger (35) reported in 1961 that forearm flexor and extensor strength in females was equal to 55 percent of male strength, using older subjects. His results indicated this difference to be only twenty percent at age fourteen, but that the difference became larger and larger as years passed.

Clarke and Wickens (19) reported boys at age nine had a mean grip strength of eighteen kilograms, while the mean left grip was seventeen pounds. A slow steady rise occurred until age twelve when grip strength rose sharply until fourteen years of age, when it levelled off.

Fleishman (30)recently used large sample groups and found for hand grip strength that girls of age fifteen gained a mean of twelve pounds over girls aged fourteen. For boys large mean differences occurred between ages thirteen, fourteen and sixteen years.

CHAPTER III

METHODS AND PROCEDURE

Description of the Apparatus

Strength Testing Machine. The strength testing machine, which followed a Hettinger idea, was used for eight of the ten tests of basic strength carried out. A vertical pole six feet long was attached to a heavy metal base that was three feet square. To the pole was attached a seat which could be lifted or lowered to accommodate subjects of unequal sizes. Two seats were interchangeable, one a small toy tractor seat for the younger or smaller subjects, and the other a regular tractor seat for all the other subjects. Slightly higher on the pole was a shaft to which horizontal arms were attached. To the horizontal arms two elbow holders were fastened. The elbow holders stabilized the upper arms both in a vertical line and laterally. They were completely adjustable through use of a sliding, but lockable system. The third attachment to the vertical pole held two shoulder pads, which were adjustable. These adjustable pads stabilized the shoulders to prevent both excessive lifting of the shoulders and forward rotation. A V bar was attached to the top of the vertical pole. The V bar was used to attach a chain during the elbow extension tests. The base of the apparatus contained a set of adjustable hooks to which chains could be fastened for the elbow flexion and leg extension tests. The machine was completed by addition of short chains, precision width cables, web-belt loops and hooks, and a Pacific Scientific Instrument cable tensiometer. The grip strength test was also carried out in the strength testing machine, using a Smedley Adjustable grip dynamometer.

Back and Leg Lift Apparatus. The back and leg lift were both carried out using a small stool which the subjects stood on. A cable was attached

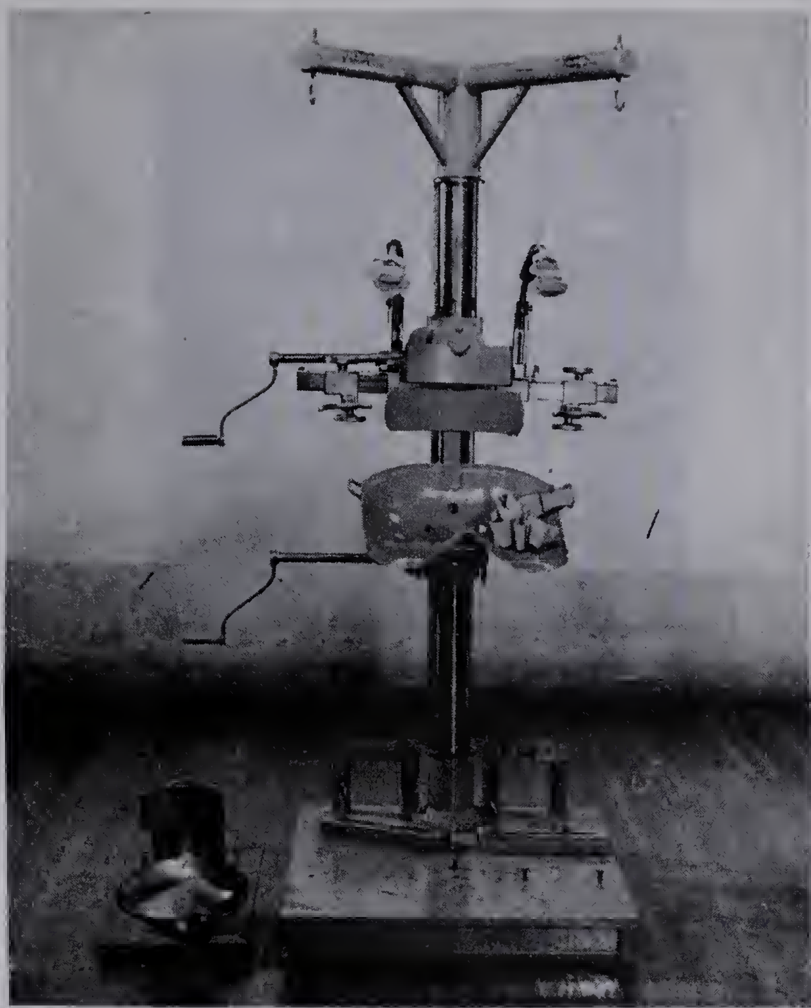

ILLUSTRATION I STRENGTH TESTING MACHINE – FRONT VIEW

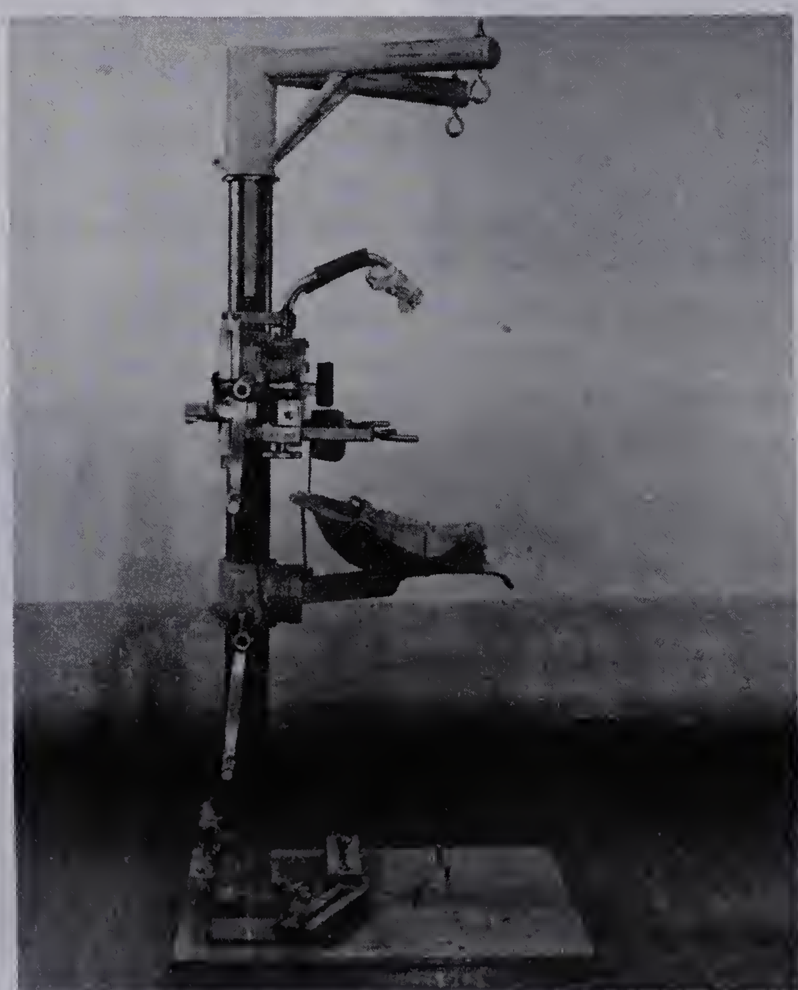

ILLUSTRATION II STRENGTH TESTING MACHINE – SIDE VIEW

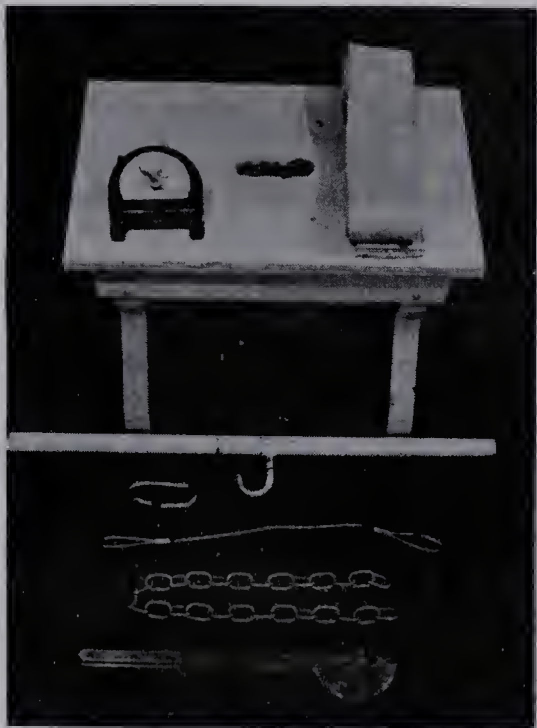

ILLUSTRATION III LEG LIFT AND BACK LIFT TEST APPARATUS

ILLUSTRATION V DETECTO SCALE

ILLUSTRATION IV SMEDLEY ADJUSTABLE GRID DYNAMOMETER, CABLE TENSIOMETERS, GONIOMETER, CABLE, AND ATTACHMENTS

to a bolt just beneath the surface of the stool. A metal gripping bar and a web belt was used for the leg lift. The belt was not used for the back lift. A Pacific Instrument Company cable tensiometer was used to record the strength of each pull. Leg angle was checked by a goniometer, and was set at 120 degrees flexion.

Selection of the Subjects

The subjects were a random sample of both public and separate school children in Edmonton, Alberta, Canada, in 1965 and 1966. Two preliminary interviews with Mr. H.McCormack of the Dominion Bureau of Statistics (Edmonton) indicated the method of drawing the sample. On the advice of the Bureau a random sample of five elementary, five junior high school, and five senior high schools was taken. This was done by using a list of all schools and a table of random numbers. Appendix B contains a list of the schools chosen at random. Cooperation was obtained from both the Public and Separate School Board officials. Following the drawing of the sample schools, complete lists of each age level of each sex were compiled, from all of these schools. At this point a table of random numbers (25) was again used to draw out 1.25 percent of each sex at each age level. This resulted in a sample size of 39 females and 36 males at each age level. A reserve sample of five subjects per age per sex was also drawn.

Description of the Tests

The tests were given in the following order:

Grip Strength Test. The strength of grip was tested for each grip by use of a Smedley Adjustable Grip dynamometer. After being seated in the strength machine the subject was instructed as to the manner of carrying

out the squeeze action. The testing arm was flexed as far as possible, and the hand held the dynamometer with the dial facing away from the subject. For subjects seven to eight years of age the adjustable dynamometer was set to number three positions, while for all other ages the setting was number four. The hand was neither supinated nor pronated but was vertically positioned while doing the test. Turning or rotating of the hand was not allowed. As the subject commenced squeezing he dropped his lower arm until it reached 90 degrees flexion. The subject was allowed six seconds for each squeeze. A brief rest was allowed between each squeeze while the reading from the dynamometer was taken and recorded. After squeezing maximally three times with the right grip, the subject carried out three left hand squeezes. Verbal encouragement or the shout technique was used at all times during the test. The subject was not aware of the results during the testing period.

Elbow Flexion Test. This test was carried out by the use of the strength machine after the shoulder and elbow holders had been adjusted. These adjustments consisted of having the subject assume a comfortable upright sitting position with the shoulders back and evenly balanced; and of having the subject's elbows against his sides and adjusted forward or backward so his upper arm was vertical. The hands remained vertical and clenched throughout the test. Using a goniometer the angle at the elbow was adjusted to 120 degrees. A belt loop was then placed around the arm and positioned exactly midway between the wristbone and the olecranon process. A cable and chain was snapped to the loop and attached to the adjustable hook at the base of the machine. The hook was adjusted to the perpendicular with the lower arm, and so that the angle of pull was straight. Using a Pacific cable tensiometer attached to the cable

ILLUSTRATION VI TEST OF RIGHT GRIP STRENGTH

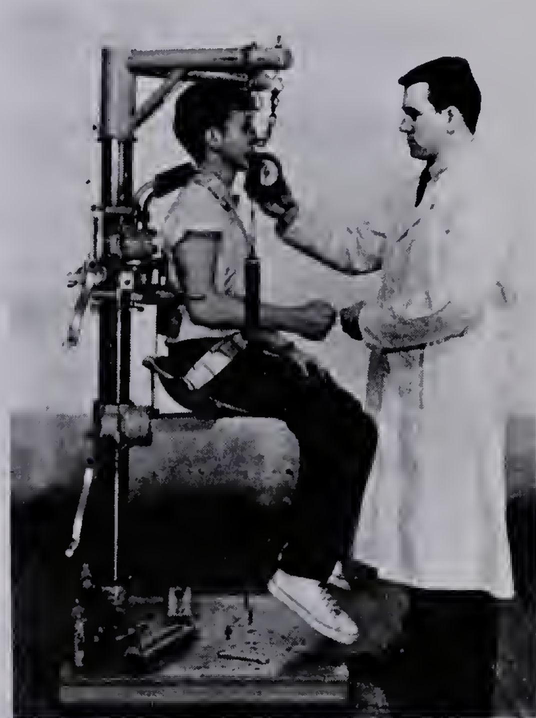

ILLUSTRATION VIII TEST OF ELBOW EXTENSION STRENGTH

ILLUSTRATION VII TEST OF ELBOW FLEXION STRENGTH

the subject flexed against the taut cable as hard as possible for six seconds. As with the grip test he did three tests with his right arm followed by three tests with his left arm. Verbal encouragement and brief rests were used throughout.

Elbow Extension Test. The overall was exactly as for the elbow flexion test. The differences in technique included: adjusting the angle of the elbow to 90 degrees; attaching the cable and chain to the V arm of the strength machine, which is located at the top of the vertical pole; and having the subject extend his lower arm downwards against the taut cable emphasizing bending of the lower arm at the elbow rather than pushing. The tendency to push was also opposed by the opposite shoulder pad.

Knee Extension Test. The subject remained in the strength machine with his hands placed lightly on his legs. A belt loop was placed around the subject's lower leg midway between the malleolus and the knee bone. The angle at the knee was adjusted to 120 degrees. The cable and chain was then fastened to one of a series of hooks placed at the perpendicular to the lower leg and adjusted laterally so the angle of pull was zero. The tester held an object in line with the proper angle of pull so the subject's maximal extension was properly aligned. Three extensions with the right leg were followed by three with the left leg. Brief rests were used along with the shout technique in doing the test. The subject left the strength machine after the knee extension test.

Leg Lift Test. The test of leg lift strength was similar to that described by Clarke (20). A small twelve inch stool was placed against a flat wall. The subject stood on the stool with his feet parallel and shoulder width apart. A metal bar was gripped by the subject with one

ILLUSTRATION IX TEST OF KNEE EXTENSION STRENGTH

ILLUSTRATION XI TEST OF BACK LIFT STRENGTH

ILLUSTRATION X TEST OF LEG LIFT STRENGTH

hand prone and one supine, and with arms bent. Attached to the bar and leading around the subject's back at hip level was a three inch web belt, which aided the subject in performing a maximal lift. The belt rested just over the top edge of the hip bone. After adjusting the knee angle to 120 degrees and checking to see that the subject's back was against the wall the subject pulled vertically upward by attempting to straighten his legs. A taut chain and cable prevented this, and held the Pacific Instrument cable tensiometer. The subject performed three maximal leg lifts.

Back Lift Test. The back lift was similar to the Clarke (20) back lift. The belt used for the leg lift was discarded but the subject remained on the stool. The subject bent forward at the hips and with arms straight he grasped the bar. The legs were straight throughout the test. The chain and cable were adjusted so that with a maximal back lift the subject's back ended up just vertical or touching the wall. Hand position and the number of trials remained the same as previously.

Experimental Design

After suitable arrangements had been made with each school the apparatus was moved out to the school. The testing was carried out in either an extra classroom, health office, equipment room, or screened off corridor. A Detecto scale was used for the height and weight measurements.

Testing Procedure. As the subject arrived in the test room he gave his name, address, phone number, and birthday. The subject also was asked which hand he wrote with. The subjects height and weight were then recorded with shoes and regular clothing on. A short explanation and request for maximum

effort followed. The subject then sat in the strength testing machine and minor adjustments were carried out. Test number one, the test of strength of grip was then begun. The order of testing was standard throughout the experimental period.

Length of Experiment. The testing commenced in June, 1965 after a one-month period of practice testing was carried out by the two testers. During July and August the testing continued. Through use of letters of request and explanation to parents, appointments were set up, and the children went to the school they had attended in June for their testing. Further testing was carried out in the schools from September until December, 1965. The older subjects were completed during January and February, 1966.

Test Administration. All of the testing was carried out by two testers. One was the author and the other was a research assistant of the Faculty of Graduate Studies in Physical Education. The same research assistant worked during the summer as well as the fall and winter testing periods.

Equipment Calibration. All calibration of the tensiometers was carried out by the Instrument Laboratory, of Northwest Industries Limited of Edmonton.

Statistical Procedures

The statistics included the following calculations:

1) Means, standard deviations, and variability for each age and sex group.

2) Analysis of significant differences between sexes, and between age groups within sex.

3) Correlation coefficients for height and weight with mean strength scores, and

dextrality coefficients.

4) Test-retest coefficients of reliability.

5) Odd versus even coefficients of reliability.

6) Relative gain in percent over the previous sample mean.

7) Correlation coefficients between the strength measures.

8) Percentile norms of all of the strength measures.

CHAPTER IV

RESULTS AND DISCUSSION

The sample groups tested were characterized by the following statistics of age, height, weight, and numbers. Age was taken as of the date of testing.

TABLE I

DESCRIPTIVE DATA OF THE TEST SAMPLE

Mean Age (yrs. mths.)	Mean Height (inches)	Mean Weight (lbs.)	Number of Subjects	Mean Age (yrs. mths.)	Mean Height (inches)	Mean Weight (lbs.)	Number of Subjects
G I R L S				B O Y S			
7-6.19	49.36	55.86	36	7-4.83	49.79	56.46	43
8-6.25	50.62	57.27	43	8-5.25	51.12	61.82	40
9-5.53	54.02	68.59	45	9-6.78	53.90	68.54	33
10-4.56	55.19	72.19	46	10-5.52	55.65	77.99	40
11-5.83	58.72	87.04	43	11-5.04	57.56	87.91	48
12-6.60	60.90	96.90	41	12-5.36	61.11	99.02	36
13-4.09	62.28	108.03	32	13-4.86	62.78	105.08	37
14-6.96	63.31	116.53	32	14-7.58	66.32	136.67	31
15-7.16	63.43	120.00	30	15-6.81	67.48	134.45	33
			348				341

The following group scores were obtained by testing using the Smedley Adjustable Grip Dynamometer. The mean grip strength appears as the mean of three trials, followed by the mean difference in grip strength by pounds over the previous age's sample. In addition the standard deviations and the variances are tabled.

TABLE II

GRIP STRENGTH OF THE RIGHT HAND FOR FEMALES AGED SEVEN TO FIFTEEN

Age	Mean Grip Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	26.61	-	4.57	20.88
8	28.67	2.06	5.12	26.22
9	32.53	3.86	6.14	37.80
10	35.71	5.18	5.68	32.29
11	43.25	7.54	7.62	58.09
12	46.87	3.62	8.33	69.45
13	54.03	7.16	9.75	95.12
14	57.25	3.22	6.93	48.90
15	61.83	4.58	18.34	107.04

The following table includes the grip strength scores compiled by the sample group of age seven to fifteen males.

TABLE III

GRIP STRENGTH OF THE RIGHT HAND FOR MALES AGED SEVEN TO FIFTEEN

Age	Mean Grip Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	28.06	-	5.06	25.68
8	32.85	4.79	6.33	40.13
9	37.72	4.87	6.90	47.64
10	42.72	5.00	11.34	128.81
11	43.27	0.55	9.07	82.37
12	51.58	8.31	10.01	100.30
13	55.54	3.96	10.27	105.64
14	75.93	20.39	12.11	146.86
15	82.63	6.70	17.52	307.05

TABLE IV

GRIP STRENGTH OF THE LEFT HAND FOR FEMALES AGED SEVEN TO FIFTEEN

Age	Mean Grip Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	25.08	-	4.46	19.90
8	27.13	3.73	4.82	23.31
9	30.86	3.73	5.91	34.93
10	33.93	3.07	5.70	32.59
11	40.62	6.69	6.69	44.85
12	44.70	4.08	9.64	93.11
13	51.40	6.70	7.86	61.86
14	54.78	3.38	8.52	72.69
15	59.03	4.25	7.33	53.75

Tables IV and V represent the results compiled for the grip strength of the left hand.

TABLE V

GRIP STRENGTH OF THE LEFT HAND FOR MALES AGED SEVEN TO FIFTEEN

Age	Mean Grip Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	26.83	-	5.43	29.52
8	31.37	4.54	5.58	31.21
9	36.27	4.90	7.16	51.32
10	40.62	4.35	10.34	106.95
11	41.16	0.54	8.63	74.56
12	49.69	8.53	10.20	104.21
13	53.94	4.25	9.01	81.21
14	73.87	19.93	10.28	105.71
15	82.72	8.85	15.16	229.82

Each subject was given the Elbow (Flexion) test, in which he completed three trials. Tables VI and VII represent scores obtained by the age seven to fifteen sample groups. The scores for the right arm are presented first.

TABLE VI

ELBOW FLEXION STRENGTH OF THE RIGHT ARM FOR AGE SEVEN TO FIFTEEN FEMALES

Age	Mean Flexion Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	24.50	-	4.06	16.54
8	25.48	0.98	4.25	18.11
9	28.91	3.43	6.65	44.31
10	33.36	4.45	5.69	32.41
11	39.83	6.47	8.38	70.28
12	43.14	3.31	10.35	107.22
13	47.56	4.42	9.94	98.83
14	39.43	-8.13	9.67	93.67
15	48.70	9.27	8.59	73.94

TABLE VII

ELBOW FLEXION STRENGTH OF THE RIGHT ARM FOR AGE SEVEN TO FIFTEEN MALES

Age	Mean Flexion Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	24.11	-	4.98	24.31
8	28.67	4.56	6.00	36.00
9	33.12	4.45	6.42	41.29
10	36.69	3.57	8.28	68.57
11	39.60	2.91	8.70	75.77
12	48.44	8.84	11.97	143.28
13	55.64	7.20	13.54	183.40
14	67.51	11.87	18.80	353.65
15	77.06	9.55	18.96	159.68

TABLE VIII

ELBOW FLEXION STRENGTH OF THE LEFT ARM FOR AGE SEVEN TO FIFTEEN FEMALES

Age	Mean Flexion Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	23.97	-	5.07	25.79
8	25.44	1.47	5.34	28.58
9	30.42	4.98	7.73	59.74
10	34.39	3.97	7.03	49.48
11	38.67	4.28	7.92	62.84
12	42.41	3.74	10.48	109.99
13	46.46	4.05	8.73	76.38
14	40.59	-5.87	9.28	86.11
15	46.60	6.01	8.72	76.04

TABLE IX

ELBOW FLEXION STRENGTH OF THE LEFT ARM FOR AGE SEVEN TO FIFTEEN MALES

Age	Mean Flexion Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	25.00	-	5.78	33.52
8	28.07	3.07	5.35	28.68
9	33.51	5.44	7.15	51.25
10	35.87	2.36	7.66	58.72
11	39.06	3.19	9.63	92.74
12	48.33	9.27	12.47	155.54
13	54.83	6.50	13.92	193.86
14	65.41	10.58	17.40	302.85
15	73.15	7.74	18.62	346.84

The Elbow Flexion strength of the left arm as tested in the seven to fifteen year old samples, resulted in the scores compiled in Tables VIII and IX. Results from both male and female samples are included.

The sample groups were tested for strength of the arm extensors. The results were compiled with the elbow at an angle of 120 degrees. The mean of three trials per subject is presented in Tables X and XI. Right arm scores are presented first.

TABLE X

ELBOW EXTENSION STRENGTH OF THE RIGHT ARM FOR AGE SEVEN TO FIFTEEN FEMALES

Age	Mean Extension Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	19.88	-	3.86	14.95
8	21.72	1.84	3.48	12.11
9	24.40	2.68	5.63	31.79
10	27.58	3.18	4.67	23.80
11	33.09	5.51	6.60	43.56
12	36.65	3.56	11.44	131.03
13	40.62	3.97	11.47	131.79
14	35.81	-4.81	7.98	63.83
15	39.96	4.15	8.48	71.96

TABLE XI

ELBOW EXTENSION STRENGTH OF THE RIGHT ARM FOR AGE SEVEN TO FIFTEEN MALES

Age	Mean Extension Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variation
7	21.46	-	5.16	26.62
8	25.40	3.94	5.12	26.29
9	28.00	2.60	5.54	30.75
10	31.85	3.85	6.31	39.92
11	33.70	1.85	6.80	46.29
12	38.72	5.02	8.43	71.17
13	43.35	4.63	9.86	97.40
14	56.80	13.45	13.12	172.16
15	65.36	8.56	16.74	280.48

TABLE XII

ELBOW EXTENSION STRENGTH OF THE LEFT ARM FOR AGE SEVEN TO FIFTEEN FEMALES

Age	Mean Extension Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variation
7	20.41	-	4.84	23.45
8	21.3	0.89	3.61	13.0
9	24.88	3.58	5.11	26.14
10	27.26	2.38	4.75	22.59
11	31.53	4.27	5.54	30.77
12	35.82	4.29	9.48	89.99
13	42.46	6.64	12.65	160.12
14	35.46	- 7.00	7.44	55.48
15	39.30	3.84	5.80	33.73

TABLE XIII

ELBOW EXTENSION STRENGTH OF THE LEFT ARM FOR AGE SEVEN TO FIFTEEN MALES

Age	Mean Extension Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variation
7	21.79	-	4.88	23.88
8	24.63	2.83	4.59	21.11
9	26.66	2.04	5.78	33.47
10	29.92	3.26	5.63	31.76
11	34.06	4.14	7.13	50.95
12	38.94	4.88	8.17	66.85
13	44.16	5.22	11.32	128.25
14	55.67	11.51	15.04	226.29
15	64.24	8.57	17.67	312.37

Tables XII and XIII present the results of the Elbow Extension strength test for male and female samples. The scores presented in the two tables are those of the left arm.

A Knee Extension test was carried out on the male and female sample groups. The scores for this parameter are presented in Tables XIV and XV for the right leg.

TABLE XIV

KNEE EXTENSION STRENGTH OF THE RIGHT LEG FOR AGE SEVEN TO FIFTEEN FEMALES

Age	Mean Extension Strength (lbs.)	Mean Difference (lbs.)	Standard Variation	Variance
7	46.77	-	10.37	107.72
8	51.02	4.25	12.23	149.64
9	61.15	10.13	17.75	315.27
10	68.95	7.80	15.77	248.84
11	75.39	6.44	18.95	359.21
12	83.31	7.92	21.88	479.07
13	92.53	9.22	20.40	416.38
14	81.37	-11.16	19.15	367.0
15	85.8	4.43	25.27	638.78

TABLE XV

KNEE EXTENSION STRENGTH OF THE RIGHT LEG FOR AGE SEVEN TO FIFTEEN MALES

Age	Mean Extension Strength (lbs.)	Mean Difference (lbs.)	Standard Variation	Variance
7	43.72	-	12.11	146.72
8	52.57	8.55	11.59	134.45
9	63.90	11.63	12.49	156.08
10	69.52	5.62	14.35	205.94
11	78.25	8.72	18.56	344.56
12	84.13	5.89	20.59	423.95
13	87.27	3.14	22.23	494.53
14	113.12	25.85	27.40	751.18
15	119.96	6.84	31.77	1009.84

TABLE XVI

KNEE EXTENSION STRENGTH OF THE LEFT LEG FOR AGE SEVEN TO FIFTEEN FEMALES

Age	Mean Extension Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variation
7	46.52	-	12.26	150.54
8	49.02	2.50	12.21	149.16
9	63.31	14.29	18.51	342.81
10	68.80	5.49	16.32	266.42
11	72.80	4.00	18.95	359.21
12	80.41	7.61	22.90	524.69
13	90.90	10.49	20.24	409.95
14	77.99	-12.91	19.17	367.80
15	85.39	7.40	23.73	563.14

TABLE XVII

KNEE EXTENSION STRENGTH OF THE LEFT LEG FOR AGE SEVEN TO FIFTEEN MALES

Age	Mean Extension Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	42.00	-	10.09	101.95
8	50.84	8.84	11.88	141.25
9	62.84	12.00	14.04	197.13
10	67.17	4.33	14.42	208.04
11	77.35	10.18	19.75	390.44
12	83.80	6.45	22.31	497.76
13	86.27	2.47	22.84	521.81
14	105.70	19.43	21.89	497.47
15	118.57	11.87	27.53	757.81

Tables XVI and XVII contain the scores resulting from the Knee Extension test with the left leg. Samples from age seven to fifteen were tested.

All of the subjects were given the Leg Lift test. Each subject completed three trials, and Tables XVIII and XIX contain the scores for the male and the female samples.

TABLE XVIII

LEG LIFT STRENGTH FOR AGE SEVEN TO FIFTEEN FEMALES

Age	Leg Lift Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	110.72	-	40.94	1676.26
8	129.37	18.65	35.54	1263.50
9	181.60	52.23	68.06	4633.42
10	202.41	20.81	57.55	3312.55
11	227.97	25.56	78.63	6183.30
12	259.70	31.73	103.89	10793.26
13	261.46	1.76	93.12	8673.09
14	227.37	-34.09	79.40	6305.59
15	262.86	35.49	110.90	12300.80

TABLE XIX

LEG LIFT STRENGTH FOR AGE SEVEN TO FIFTEEN MALES

Age	Leg Lift Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variation
7	115.72	-	37.61	1414.63
8	145.55	22.83	44.37	1968.76
9	194.45	48.90	50.67	2568.31
10	213.52	19.07	57.86	3348.20
11	248.39	34.87	83.44	6962.49
12	285.77	37.38	106.32	11304.00
13	324.56	38.79	99.58	9916.53
14	364.67	40.11	93.80	8799.29
15	427.42	62.75	145.39	21138.81

TABLE XX

BACK LIFT STRENGTH FOR AGE SEVEN TO FIFTEEN FEMALES

Age	Back Lift Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variation
7	66.63	-	19.31	373.20
8	71.32	4.69	13.12	172.32
9	85.62	14.30	21.81	476.01
10	94.45	8.83	16.82	283.18
11	113.65	19.20	23.12	534.70
12	128.63	14.98	29.11	847.78
13	142.71	14.08	24.53	601.82
14	136.09	- 6.62	24.74	612.34
15	141.96	5.87	21.36	456.51

The next set of results were obtained from the test of Back Lift strength. Tables XX and XXI contain the results of that test. The previous Table indicated the scores for the female sample, while the following Table is the male sample.

TABLE XXI

BACK LIFT STRENGTH FOR AGE SEVEN TO FIFTEEN MALES

Age	Back Lift Strength (lbs.)	Mean Difference (lbs.)	Standard Deviation	Variance
7	73.13	-	15.00	225.12
8	80.82	7.69	16.95	287.37
9	103.66	22.84	22.46	504.85
10	106.80	3.14	18.93	358.36
11	121.64	14.84	21.83	476.91
12	144.38	22.74	29.95	897.55
13	157.72	13.34	32.99	1088.75
14	199.35	41.63	30.51	931.03
15	215.00	15.65	42.67	1803.93

Reliability Coefficients for the Strength Measurements

Two different methods of calculating reliability coefficients were used in the study. For each strength test used, the subject carried out three trials. It was decided to compare the first trial to the second trial. In the second method a random selection of the fourteen and

fifteen year old sample group was retested.

The reliability coefficients were calculated by working out the variance for trials one and two, as well as the combined variances. The total variance and the inter-individual variance also were calculated. Trial one was compared to trial two for right grip strength, left grip strength, right elbow flexion, right elbow extension, right knee extension, leg lift, and back lift. Table XXII includes the reliability coefficients for females, and Table XXIII includes the reliability coefficients for the male sample.

TABLE XXII

TEST RETEST RELIABILITY COEFFICIENTS FOR FEMALES

Age	7	8	9	10	11	12	13	14	15
No. of Subjects	36	43	45	46	43	41	32	32	30
Grip-Right	0.80	0.82	0.84	0.78	0.81	0.87	0.94	0.79	0.90
Grip-Left	0.80	0.96	0.87	0.84	0.77	0.91	0.85	0.83	0.85
Elbow Flexion	0.90	0.70	0.91	0.90	0.92	0.94	0.93	0.94	0.90
Elbow Extension	0.83	0.81	0.93	0.92	0.95	0.97	0.92	0.89	0.88
Knee Extension	0.89	0.89	0.87	0.86	0.93	0.86	0.86	0.82	0.93
Leg Lift	0.92	0.88	0.91	0.88	0.92	0.95	0.91	0.93	0.93
Back Lift	0.88	0.93	0.93	0.83	0.90	0.94	0.87	0.85	0.79

TABLE XXIII

TEST RETEST RELIABILITY COEFFICIENTS FOR MALES

Age	7	8	9	10	11	12	13	14	15
No. of Subjects	43	40	33	40	48	36	37	31	33
Grip-Right	0.73	0.81	0.83	0.95	0.90	0.89	0.97	0.81	0.94
Grip-Left	0.86	0.87	0.92	0.90	0.95	0.94	0.90	0.78	0.89
Elbow Flexion	0.86	0.88	0.91	0.94	0.87	0.91	0.93	0.87	0.94
Elbow Extension	0.88	0.90	0.93	0.91	0.95	0.98	0.89	0.95	0.97
Knee Extension	0.85	0.82	0.74	0.86	0.88	0.88	0.94	0.98	0.98
Leg Lift	0.87	0.88	0.89	0.64	0.87	0.93	0.92	0.91	0.93
Back Lift	0.59	0.91	0.84	0.88	0.79	0.91	0.94	0.81	0.94

The second type of reliability coefficient appears in Table XXIV. These reliabilities have been computed from subjects who were given a complete retest. The retest varied from seven to twenty-two days after the original test. The mean test-retest interval was 20.15 days. The mean age of the group was 176.9 months. Picked at random, they included some subjects fourteen years and some fifteen years of age. Females and males were included.

TABLE XXIV

TEST-RETEST RELIABILITY COEFFICIENTS

Grip-Right	Grip-Left	Elbow Flexion	Elbow Extension	Knee Extension	Leg Lift	Back Lift
0.91	0.95	0.96	0.84	0.90	0.81	0.92
N=23	N=23	N=21	N=21	N=21	N=21	N=20

Growth Curves Based on Cross Sectional Data. Figures III and IV portray the mean score of the sample groups for the Dynamometer grip strength test. The standard deviation for each mean has also been included in the figures. The male standard deviations are graphed above the male means; while the female standard deviations are below the female means. The standard deviation is the vertical difference between the two graphed points. A test for homogeneity/heterogeneity of variance (25) between the means was first carried out. The "t" score calculation was then carried out according to the method outlined by Edwards (25:106-07). The curves drawn for the right and left grip means were similar. The sex samples tested for strength of right grip had significantly differing means at the eight year, nine year, ten year, fourteen year, and fifteen year levels. The most nearly vertical ascent for consecutive female sample groups occurred in the ten year old to the eleven year old samples. For consecutive male samples the most nearly vertical ascent occurred between thirteen and fourteen years. Tables II to V illustrate that the right grip strength of males is stronger than the left grip at all ages except fifteen years. The same tables show that, for females, the mean grip strength of the right hand is greater than the grip of the left hand.

The samples tested for strength of left grip had significantly differing means at nine year, ten year, fourteen year, and fifteen year levels. The eight year samples were not significantly different, as they were for the test of right grip strength. The standard deviations for the left grip scores increased as the years of age increased. A similar pattern for this character occurred in both the male and female examples. This characteristic was not different for right hand grip strength scores.

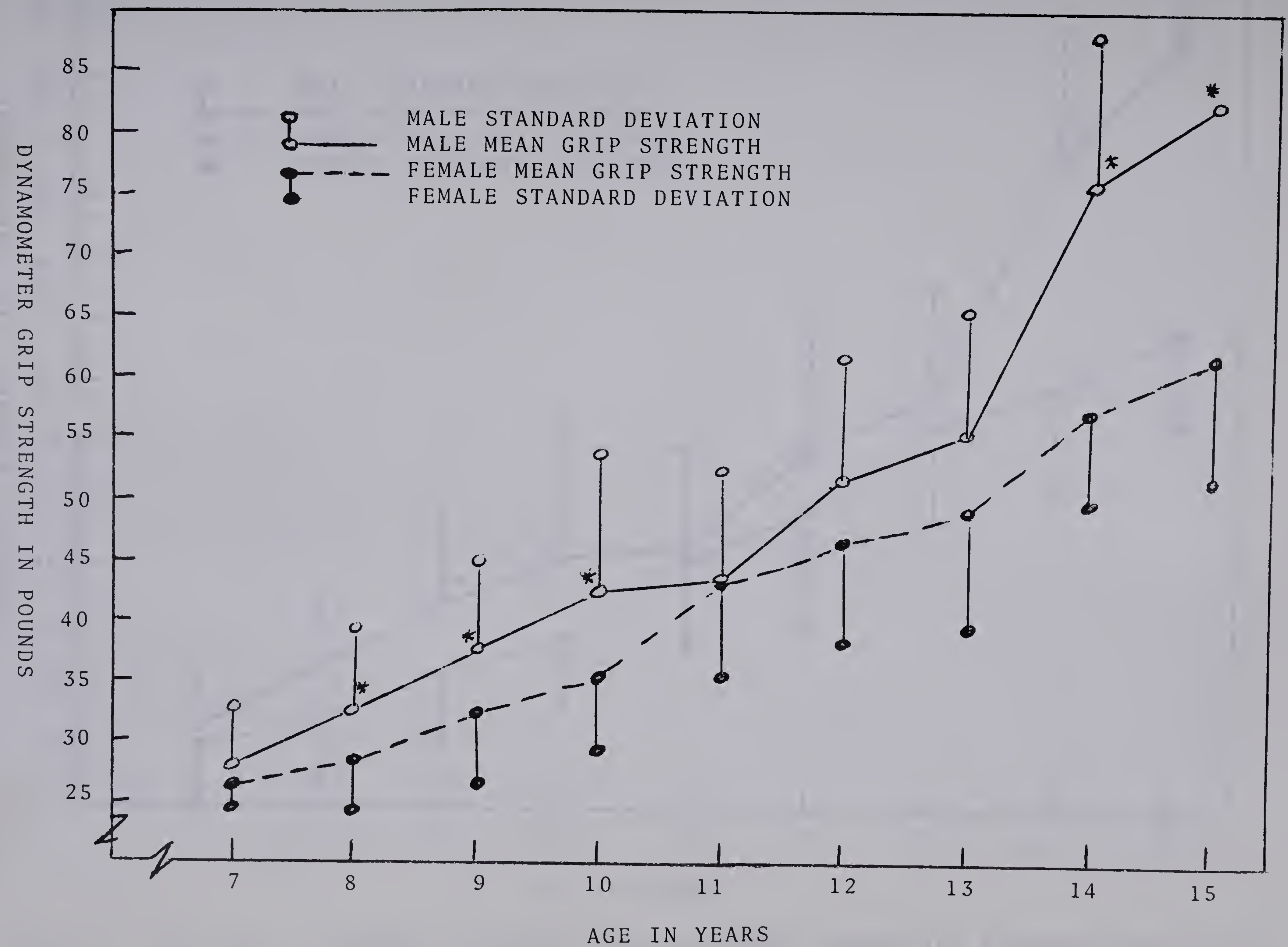

FIGURE III. RIGHT GRIP STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVIATIONS.
(* = difference in means significant beyond the 0.01 level of confidence)

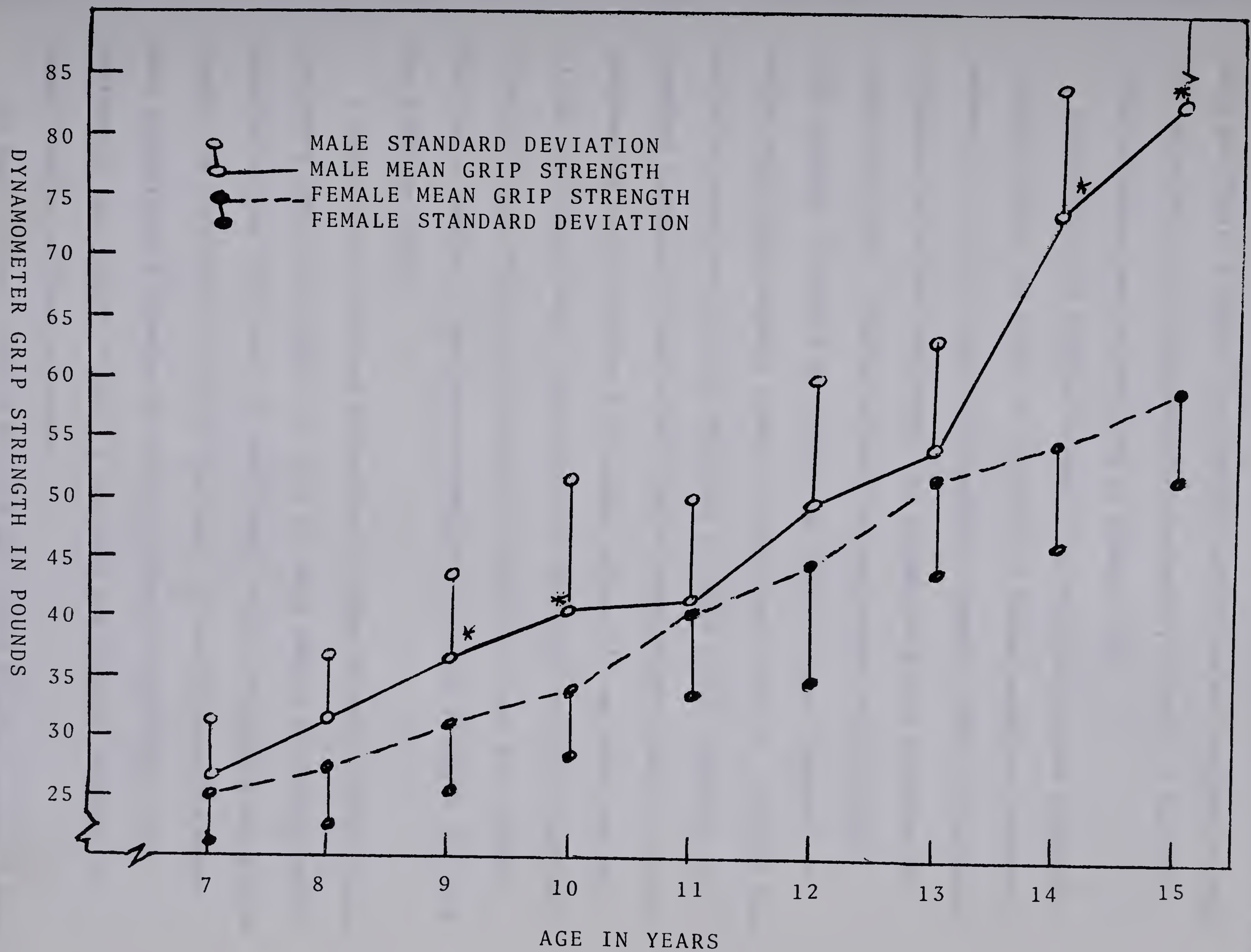

FIGURE IV. LEFT GRIP STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVIATIONS.
(* = difference in means significant beyond the 0.01 level of confidence)

Figures V and VI portray the mean elbow flexion scores for both the male and female samples. The standard deviations are included as well. The calculation for homogeneity/heterogeneity, as well as the "t" score procedure were as outlined by Edwards (25).

For right elbow flexion strength the male mean scores increased gradually until ten years. An increase of lesser magnitude occurred between the ten and eleven year samples. However, after eleven years, increased gains were the order. The largest male mean increase for consecutive years occurred between the thirteenth and fourteenth year samples. It should be pointed out that the ages discussed as whole years were somewhat closer to half years. That is, one half year above the mentioned age, as reference to Table I will indicate. The greatest increase in mean elbow flexion strength for females occurred between the ten and eleven year sample groups. At age seven and age eleven the female mean flexion strength surpassed the males, although this difference was not statistically significant (see Table XLIX). The female sample at age fourteen was lower in mean strength than the age thirteen sample.

A comparison of the sex difference in elbow flexion strength scores indicates that at age eight and nine the male sample was significantly superior at the 0.01 level of confidence. During the middle age groups tested the difference in scores was less. By age thirteen the males were significantly stronger at the 0.01 level of confidence. The difference was larger at ages of fourteen and fifteen, between the sexes' mean elbow flexion scores.

The same pattern occurred for the left elbow flexion scores. A mean difference was found in the eight and nine year old male and female samples, though these mean differences were not significant.

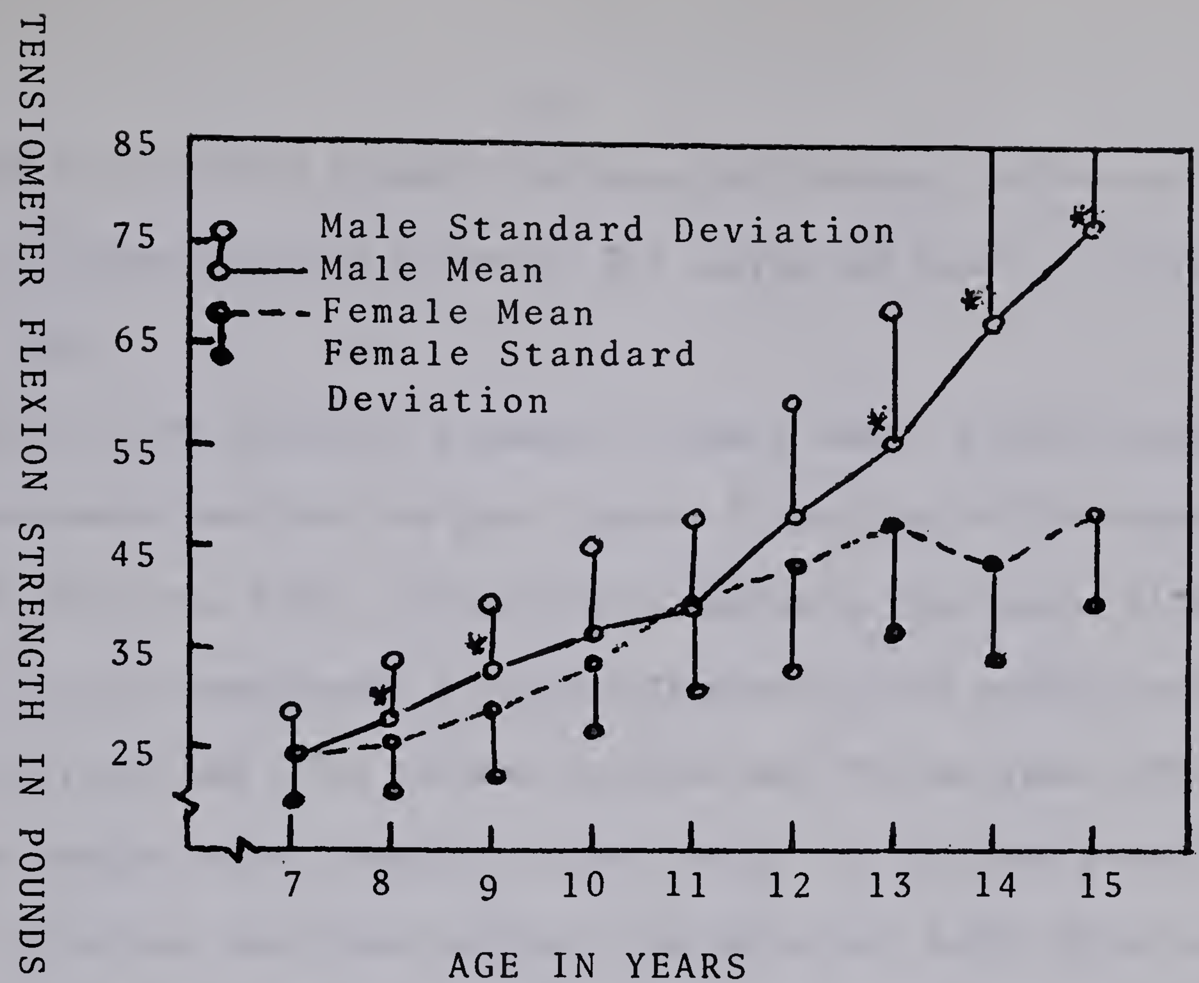

FIGURE V. RIGHT ELBOW FLEXTION STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVIATIONS.
(* = difference in means significant beyond the 0.01 level of confidence)

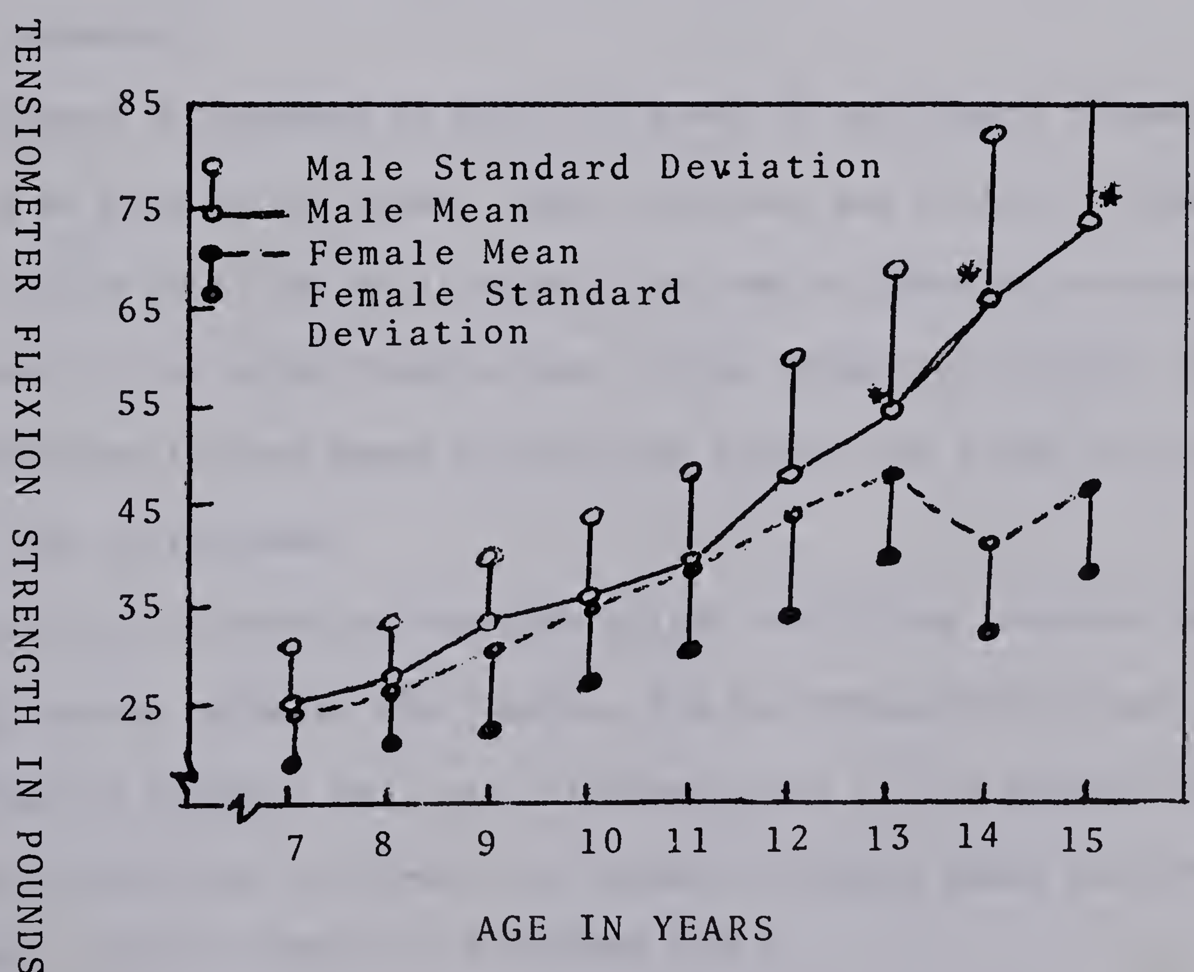

FIGURE VI. LEFT ELBOW FLEXION STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVIATIONS.
(* = difference in means significant beyond the 0.01 level of confidence)

Figures VII and VIII present the means and standard deviations for the test of elbow extension strength. The curves are based on cross-sectional data.

For right elbow extension strength the male sample gained steadily between the seven year and ten year levels. A levelling off between ten and eleven years was found; followed by a gradually increasing difference at twelve and thirteen years. A large difference (13.45 pounds) occurred at fourteen years and again between fourteen and fifteen years. For females the sample groups gained steadily between seven and thirteen years. The smallest difference was found between ages seven and eight while the largest difference was between ten and eleven years. The difference between the age thirteen and fourteen sample was, once again, negative (-4.81 pounds). Thirteen year old girls were stronger than all other female age groups for this parameter.

Significant differences at the 0.01 level of confidence between sexes, were found at ages seven, eight, nine, fourteen, and fifteen. Attention is drawn to the fact that while significant sex differences occurred at age thirteen in the elbow flexion test, elbow extension strength did not develop differently (for means significant at the 0.01 level of confidence), until the age of fourteen.

For left elbow extension strength slight variations occurred in the individual curves of males and females. The sex comparison of mean left elbow extension strength was less differentiating in the earlier years studied. A significant difference in strength between sexes was found at eight years, fourteen years, and fifteen years.

The standard deviations increased with age. There was little difference between the right and left hand scores within the same sex.

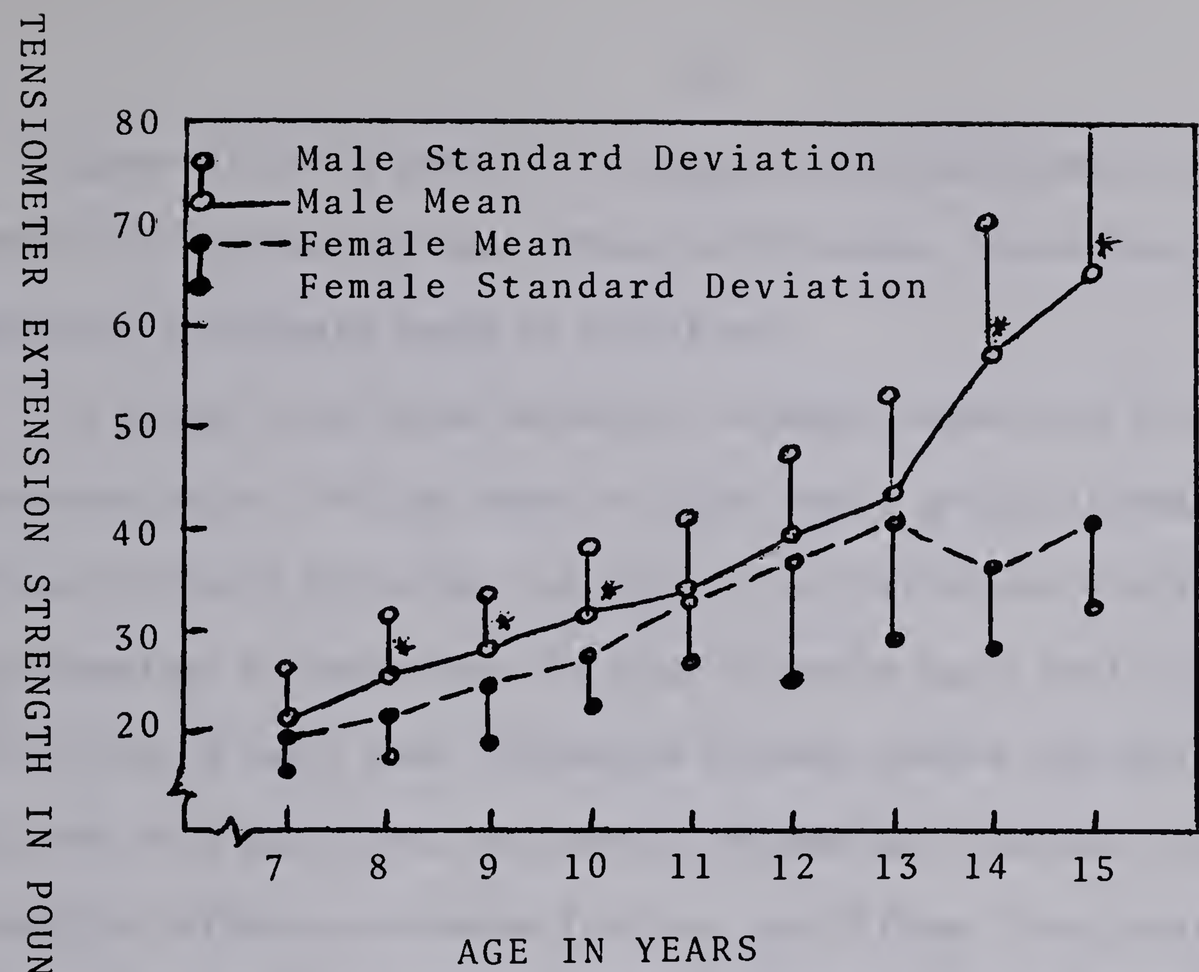

FIGURE VII. RIGHT ELBOW EXTENSION STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVIATION

(* = difference in means significant beyond the 0.01 level of confidence)

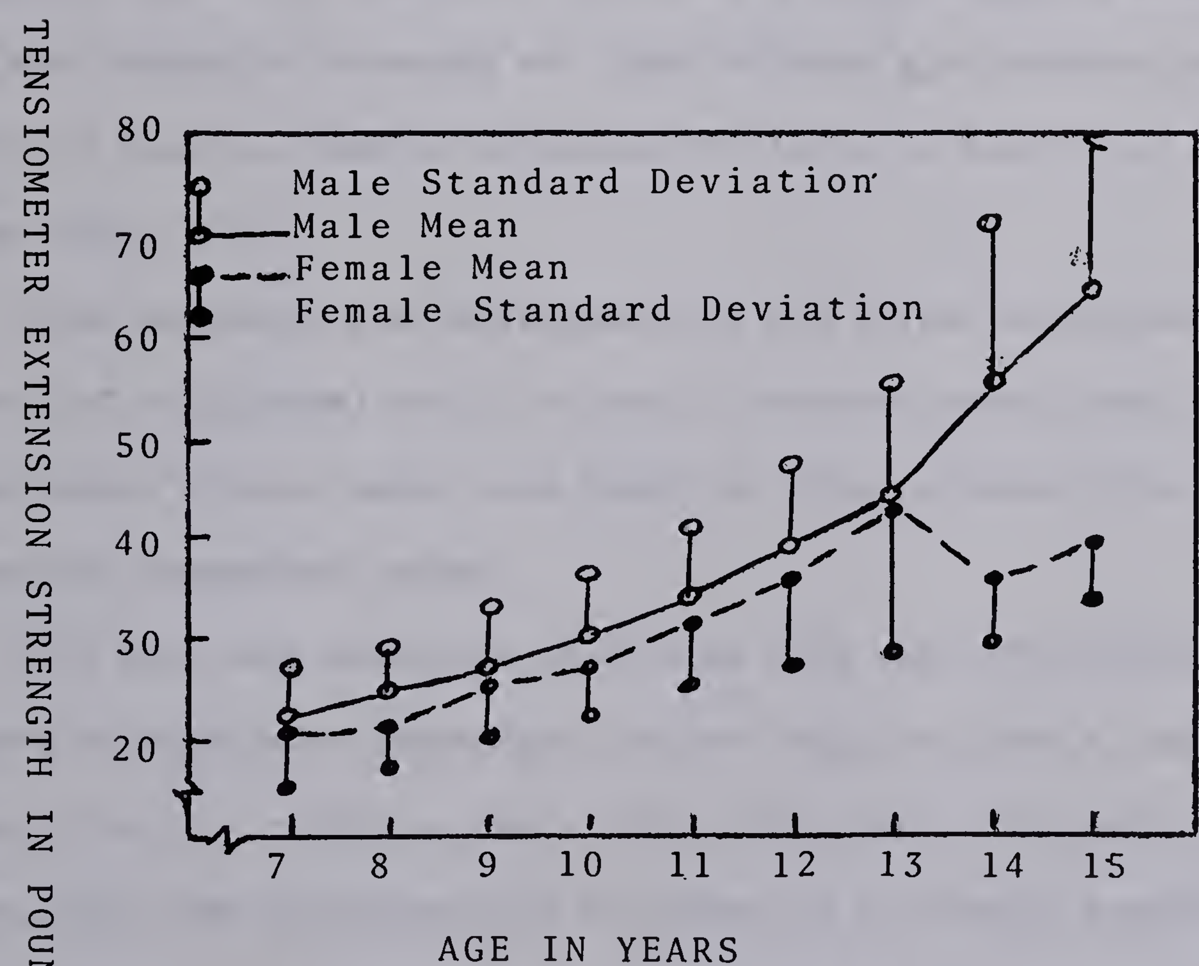

FIGURE VIII. LEFT ELBOW EXTENSION STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVIATIONS

(* = difference in means significant beyond the 0.ol level of confidence)

Figures IX and X present the means and standard deviations for all samples on the test of knee extension strength. The methods of calculation mentioned previously apply to this test.

For males, right knee extension strength showed the following characteristics. The age seven to nine sample groups increased steadily in mean strength while the age nine to ten difference was small, showing a plateauing. A steady mean increase occurred again until age twelve. After this, a small mean difference between twelve and thirteen was followed by a large mean difference between age thirteen and fourteen. A smaller difference between fourteen and fifteen then occurred. For female samples small differences were found at ages seven to eight and fourteen to fifteen. The largest mean differences occurred between ages eight to nine, and twelve to thirteen. A large negative mean difference in knee extension strength was found between age thirteen and fourteen for the females. Females surpassed the males at ages seven and thirteen (see Table LIII).

Knee extension sex differences did not differ significantly (at 0.01 level of confidence) until the age of fourteen years. More nearly equivalent means between sexes were found for this parameter than for the arm strength parameters tested.

For left knee extension there were only small fluctuations when compared to right knee extension, for both male and female samples. It was found that the right leg was slightly stronger in the male samples for all ages. The same characteristic was found in the female samples. The standard deviations increased as age increased in this parameter as well.

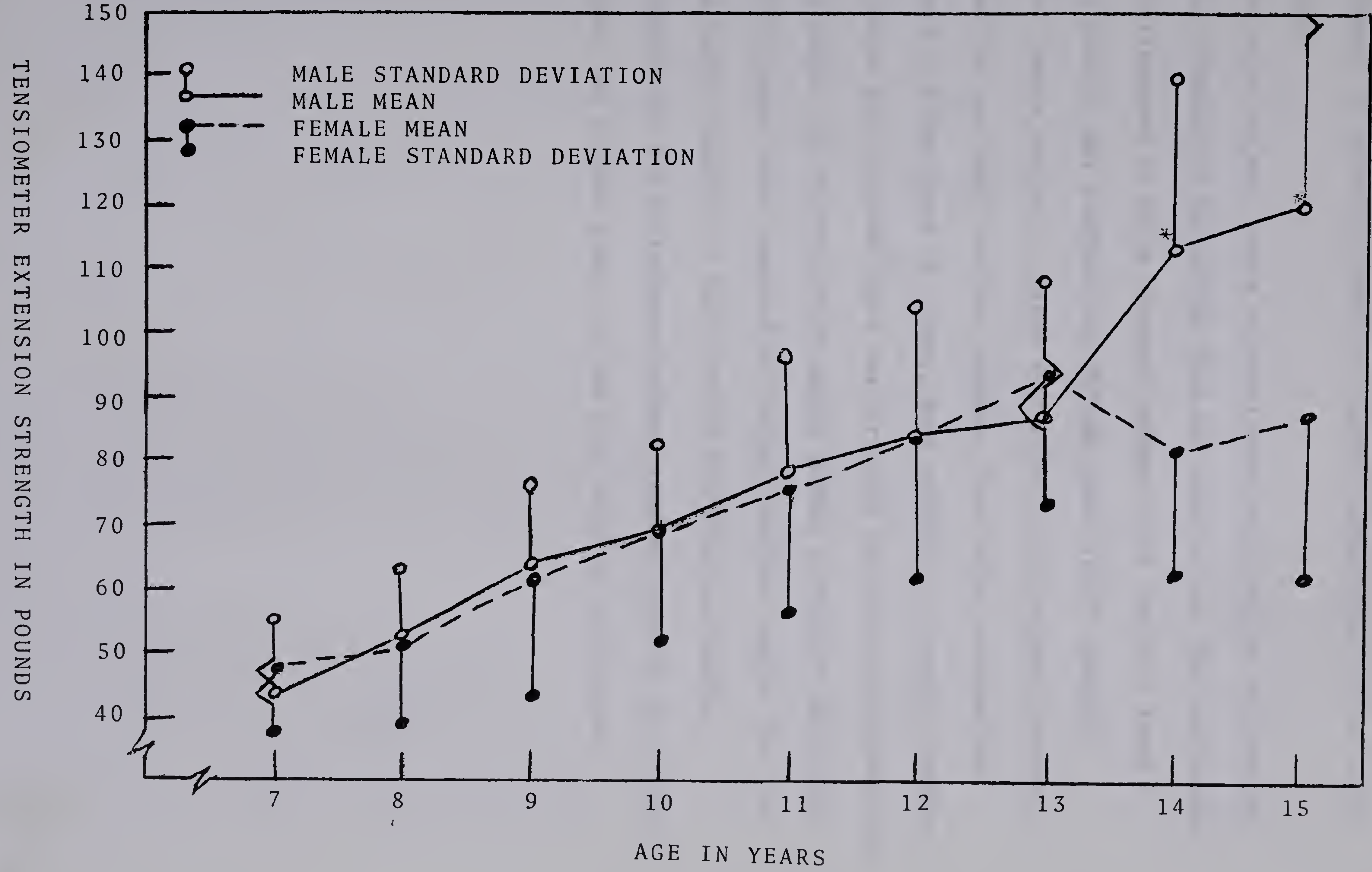

FIGURE IX. RIGHT KNEE EXTENSION STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVITATIONS.
(* = difference in means significant beyond the 0.01 level of confidence)

Figure XI shows the mean and standard deviations for leg lift strength.

For male subjects there occurred relatively smaller differences between consecutive age groups from age nine to ten. The two largest mean differences in males occurred between eight and nine years (48.90 pounds) and fourteen and fifteen years (62.75 pounds).

For female subjects a large difference (52.23 pounds) occurred between the age eight and nine samples. This large increase was followed by three years of steady, more moderate, increases. Between ages twelve and thirteen there was virutally no difference between the sample means. The fourteen year sample showed a negative difference of -34.99 pounds when compared to the age thirteen sample. The age fifteen sample reached the level of the thirteen year sample.

Significant sex differences between samples occurred at thirteen, fourteen, and fifteen years, at the 0.01 level of confidence.

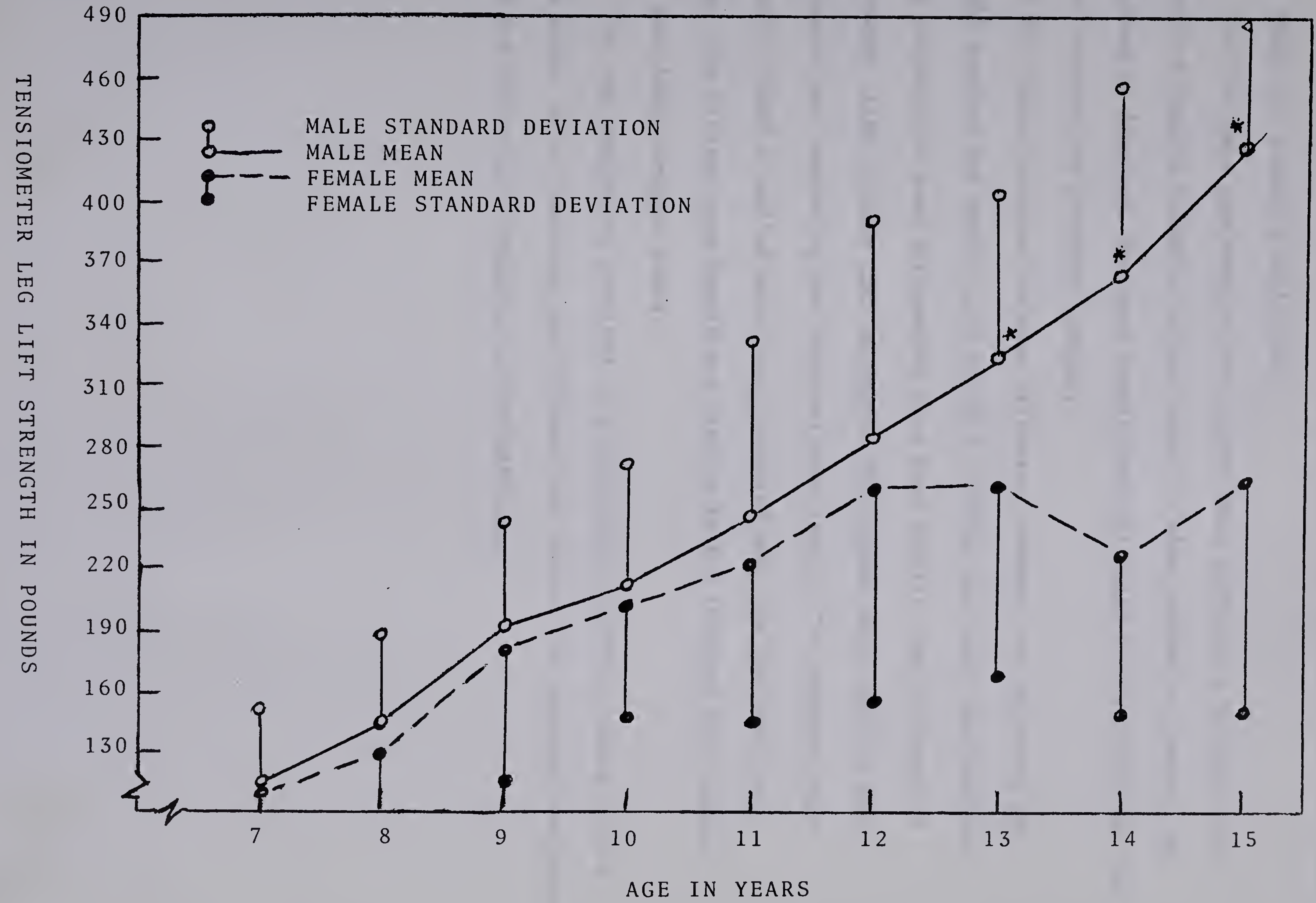

FIGURE XI. LEG LIFT STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVIATIONS.
(* = difference in means significent beyound the 0.01 level of confidence)

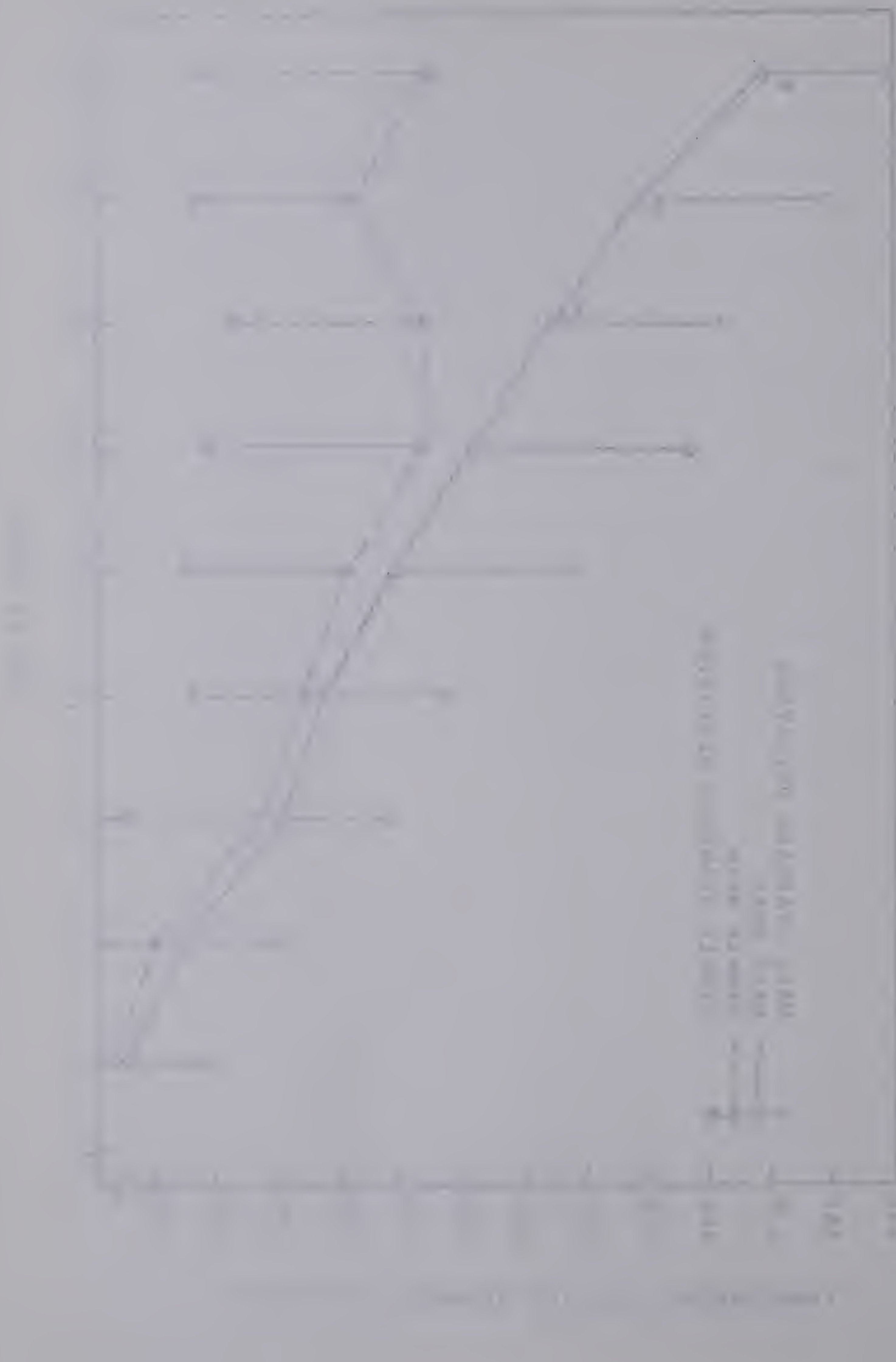

Figure XII shows the results of the back lift strength test expressed as means and standard deviations.

For the male age samples the largest mean difference between consecutive samples occurred at ages eight to nine, eleven to twelve, and thirteen to fourteen. The most nearly vertical climb occurred between the age thirteen and fourteen samples.

For female samples the mean difference between the age seven and eight samples was small (4.69 pounds). Between age eight and thirteen the consecutive mean differences were very similar, and represented a steady climb in back lift strength. The highest mean level of back strength was reached by the thirteen year sample. The fourteen year sample showed a smaller mean score compared with the thirteen year mean. The fifteen year sample was similar to the thirteen year sample in mean back strength score.

The sex comparison resulted in significantly different means at the age eight, nine, fourteen, and fifteen year levels. The standard deviations did not follow an increasing pattern with age.

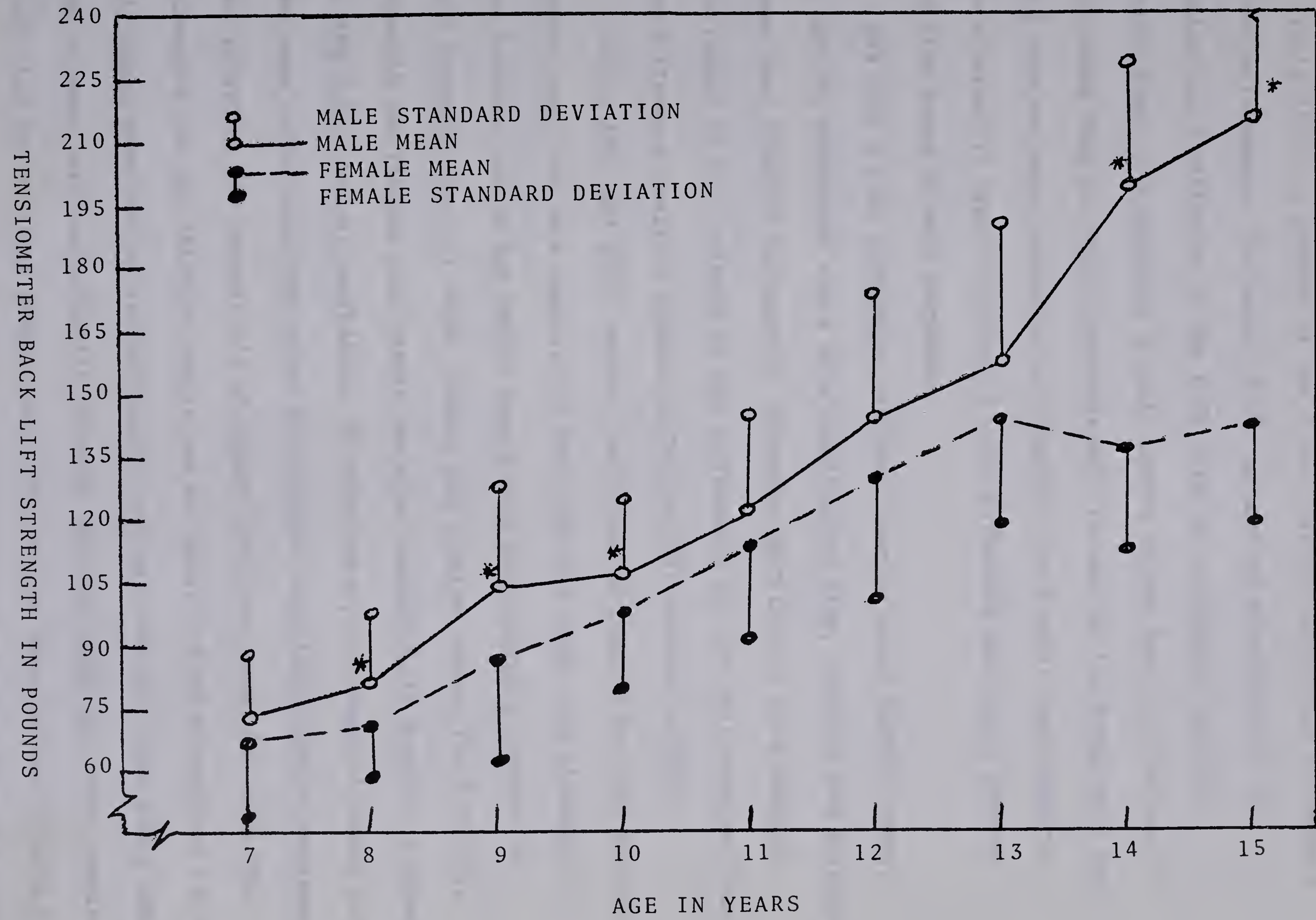

FIGURE XII. BACK LIFT STRENGTH OF MALES VERSUS FEMALES. MEANS AND STANDARD DEVIATIONS.

(* - difference in means significant beyond the 0.01 level of confidence)

Analysis of the Age Differences in Strength for the Male Samples

Table XXV is a summary of the F test carried out on all parameters of the male sample. The means of the parameters were found to be statistically different at the 0.01 level of confidence using the F-ratio test. The resulting F ratio scores ranged from 32.0 to 144.97. This means that the null hypothesis with respect to the tests does not hold true and must, therefore be rejected. The F-ratio test supports the alternative hypothesis that a real difference does exist between the nine means of each parameter.

Now that a real difference has been shown to occur between means, it must be determined where this significance lies. Duncan's New Multiple-Range Test (25:136) was used to determine specifically this unknown. The result is the analysis of age differences for the male samples. This age difference analysis appears in Tables XXVI through to XXXV.

Tables XXVI and XXVII exhibit the following results for grip strength scores among the male sample. For both left and right grip strength, an age fourteen and an age twelve sample were statistically greater in mean strength than all other younger age samples tested. For left grip strength the fifteen year sample was also statistically greater in strength at the 0.01 level of confidence. In other words, the computed Duncan scores for mean differences were above the shortest significant range requirements. The procedure for unequal n's of Kramer (1956) was used. For both grip strengths the age thirteen sample was not above the range required for significance over the twelve year sample, but was over all other young ages. Age elevens were statistically stronger than age eight and seven samples only. Age ten to eight samples were not stronger than the next lowest age sample at the 0.01 level, but were statistically stronger than all other younger age samples.

TABLE XXV
SUMMARY OF F TEST FOR ALL PARAMETERS OF THE MALE SAMPLES

Source of variation	Sum of Squares	df	Mean Square	F
1. Right Grip Strength				
Among Means of Conditions	98296.31	8	12287.0	91.68*
Within Conditions	44495.82	332	134.02	
		340		
2. Left Grip Strength				
Among Means of Conditions	100854.92	8	12606.86	144.97*
Within Conditions	28872.41	332	86.96	
		340		
3. Right Elbow Flexion				
Among Means of Conditions	92284.2	8	11535.52	85.6*
Within Conditions	44739.56	332	134.75	
		340		
4. Left Elbow Flexion				
Among Means of Conditions	80229.98	8	10037.49	76.73*
Within Conditions	43426.06	332	130.8	
		340		
5. Right Elbow Extension				
Among Means of Conditions	59887.16	8	7485.89	143.04*
Within Conditions	17699.61	332	52.7	
		340		

* F score significant beyond the .01 level of confidence.
(at α 0.01 F for 200 df = 2.60; F for 400 df = 2.55)

TABLE XXV(cont'd.)
SUMMARY OF F TEST FOR ALL PARAMETERS OF THE MALE SAMPLES

Source of Variation	Sum of Squares	df	Mean Square	F
6. Left Elbow Extension				
Among Means of Conditions	39011.79	8	4876.47	32.0*
Within Conditions	50592.1	332	152.38	
		340		
7. Right Knee Extension				
Among Means of Conditions	184298.69	8	23037.33	58.65*
Within Conditions	130387.3	332	392.73	
		340		
8. Left Knee Extension				
Among Means of Conditions	177075.	8	22134.46	62.6*
Within Conditions	117379.47	332	353.55	
		340		
9. Leg Lift Strength				
Among Means of Conditions	3065627.9	8	383203.48	64.6*
Within Conditions	1969260.6	332	5931.5	
		340		
10. Back Lift Strength				
Among Means of Conditions	707170.78	8	88396.34	127.83*
Within Conditions	229584.42	332	691.51	
		340		

* F score significant beyond the .01 level of Confidence

TABLE XXVI

DUNCAN'S NEW MULTIPLE RANGE TEST FOR GRIP STRENGTH RIGHT OF THE MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15		Shortest Significant Ranges	
N	43	40	33	40	48	46	37	32	33			
Means	28.06	32.85	37.72	42.72	43.27	51.58	55.54	75.93	82.63			
											df 120	df ∞
7		4.79	*	*	*	*	*	*	*	R_2	42.8	42.11
8			4.87	*	*	*	*	*	*	R_3	44.54	43.85
9				5.00	5.55	*	*	*	*	R_4	45.81	45.12
10					0.55	*	*	*	*	R_5	46.74	45.43
11						*	*	*	*	R_6	47.43	46.74
12							3.96	*	*	R_7	48.01	48.32
13								*	*	R_8	48.59	47.78
14									6.70	R_9	48.94	48.24

* = Difference in means significant at the 0.01 level of confidence

TABLE XXVII

DUNCAN'S NEW MULTIPLE RANGE TEST FOR GRIP STRENGTH LEFT OF THE MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15		Shortest Significant Range	
N	43	40	33	40	48	36	37	31	33			
Means	26.83	31.37	36.27	40.62	41.16	49.69	53.94	73.87	82.72			
											df 120	df ∞
7		4.54	*	*	*	*	*	*	*	R_2	34.48	33.92
8			4.90	*	*	*	*	*	*	R_3	35.88	35.32
9				4.35	4.89	*	*	*	*	R_4	36.90	36.34
10					0.54	*	*	*	*	R_5	37.65	37.00
11						*	*	*	*	R_6	38.21	37.65
12							4.25	*	*	R_7	38.67	38.11
13								*	*	R_8	39.14	38.49
14									*	R_9	39.42	38.86

* = Difference in means significant at the 0.01 level of confidence

Table XXVIII and Table XXIX aid in analyzing the age differences for the samples of males tested. For samples of fifteen, fourteen, and twelve year old males there existed mean differences in strength between age samples, that were statistically significant beyond the 0.01 level of confidence. For example, the mean difference in flexion strength between age twelve and eleven was 8.84 pounds. The Duncan's test resulted in a Range score of 56.69. This mean difference was therefore significant since the required (α0.01) level was 42.92 with df 120; and 42.22 with df . This difference held true for both right and left elbow flexion. For samples of age thirteen and age twelve a mean difference in strength of 7.20 pounds for right flexion; and 6.50 for left flexion was found. This difference was statistically significant ($\alpha = 0.01$) for the right flexion; while it was <u>not</u> for the left flexion (the left mean difference Range score = 39.26 which was just below R_2). An age eleven sample was significantly stronger than ages eight and seven only. For age ten, nine, and eight samples a significant difference was not found for the age sample just below these ages (i.e. by one year).

For age fifteen and fourteen samples doing the elbow extension test, a significant difference in scores was found over all younger ages. This held true for age thirteen and twelve samples on the <u>right</u> extension test, but not on the left extension test. Mean differences of 5.22 and 4.88 pounds did not result in Range requirements at these two ages (for left extension). A difference in sample patterns between right and left was found for ages below eleven, as well as the two just mentioned. For right extension, samples of eleven, ten, nine, and eight years where not significantly greater in mean strength than the age just below them, but were for two ages below them. This observation did not hold true for left elbow exten-

TABLE XXVIII
DUNCAN'S NEW MULTIPLE RANGE TEST FOR RIGHT ELBOW FLEXION STRENGTH OF MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Ranges		
N	43	40	33	40	48	36	37	31	33			
Means	24.11	28.67	33.12	36.69	39.6	48.44	55.6	67.51	77.06		df 120	df ∞
7		4.56	*	*	*	*	*	*	*	R_2	42.92	42.22
8			4.45	*	*	*	*	*	*	R_3	44.66	43.96
9				3.57	6.48	*	*	*	*	R_4	45.93	45.24
10					2.91	*	*	*	*	R_5	46.86	46.05
11						*	*	*	*	R_6	47.56	46.86
12							*	*	*	R_7	48.14	47.44
13								*	*	R_8	48.72	47.9
14									*	R_9	49.06	48.37

* = difference in means significant beyond the 0.01 level of confidence

TABLE XXIX
DUNCAN'S NEW MULTIPLE RANGE TEST FOR ELBOW FLEXION LEFT STRENGTH OF MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range		
N	43	40	33	40	48	36	37	31	33			
Means	25.0	28.07	33.51	35.87	39.06	48.33	54.83	65.41	73.15		df 120	df ∞
7		3.07	*	*	*	*	*	*	*	R_2	42.29	41.6
8			5.44	*	*	*	*	*	*	R_3	44.0	43.31
9				2.36	5.55	*	*	*	*	R_4	45.26	44.57
10					4.13	*	*	*	*	R_5	46.17	45.37
11						*	*	*	*	R_6	46.86	46.17
12							6.5	*	*	R_7	47.43	46.74
13								*	*	R_8	48.0	47.2
14									*	R_9	48.34	47.66

* = difference in means significant beyond the 0.01 level of confidence

TABLE XXX

DUNCAN'S NEW MULTIPLE RANGE TEST FOR RIGHT ELBOW EXTENSION OF MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range	
N	43	40	33	40	48	36	37	31	33		
Means	21.46	25.42	28.0	31.85	33.7	38.70	43.35	56.8	65.36		
										df 120	df ∞
7		3.94	*	*	*	*	*	*	*	R_2 26.82	26.39
8			2.6	*	*	*	*	*	*	R_3 27.91	27.47
9				3.85	*	*	*	*	*	R_4 28.71	28.27
10					1.85	*	*	*	*	R_5 29.29	28.78
11						*	*	*	*	R_6 29.72	29.29
12							*	*	*	R_7 30.08	29.65
13								*	*	R_8 30.45	29.94
14									*	R_9 30.66	30.23

* = difference in means significant beyond the 0.01 level of confidence

TABLE XXXI

DUNCAN'S NEW MULTIPLE RANGE TEST FOR LEFT ELBOW EXTENSION OF MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range	
N	43	40	33	40	48	36	37	31	33		
Means	21.79	24.62	26.66	29.92	34.06	38.94	44.16	55.67	64.24		
										df120	df ∞
7		2.83	4.87	*	*	*	*	*	*	R_2 45.65	44.91
8			2.04	5.3	*	*	*	*	*	R_3 47.5	46.76
9				3.26	7.4	*	*	*	*	R_4 48.86	48.12
10					4.14	*	*	*	*	R_5 49.85	48.98
11						4.88	*	*	*	R_6 50.59	49.85
12							5.22	*	*	R_7 51.21	50.47
13								*	*	R_8 51.82	50.96
14									*	R_9 52.19	51.45

* = difference in means significant beyond the 0.01 level of confidence

sion mean age differences of this same range. In other words, there was greater differentiation between successive age samples on this parameter, in favor of right elbow extension (the Appendix contains information on the handedness of the samples).

The results found for our sample groups indicate more parallel age sample tendencies for right elbow flexion when contrasted with right elbow extension; than for right elbow flexion when contrasted to left elbow flexion.

Tables XXXII and XXXIII show the results pertaining to age sample differences for the knee extension test among the males. The analysis showed that right and left knee extension scores were similar with regard to age differences, with only one exception. That exception involved the age nine sample. A mean difference of 11.33 pounds between the age nine and eight samples on the right extension test failed to reach the range level for significance (the mean difference was = 68.13 + the range level of 73.29 at df 120). However, a mean difference for left extension of 12.0 pounds was significant at the 0.01 level of confidence (Duncan's Range score = 72.15 for 12.0 pounds). The age fifteen and the age fourteen samples were significantly above all other younger age samples on the knee extension test of the male samples. Age thirteen boys were found to be not significantly greater in extension strength (α=0.01) than age twelve or eleven samples, while they were for all other younger ages. Age twelve, eleven, and ten year samples were significantly above the age samples that were two years younger in age and below. Age eight sample scores were not statistically greater (α = 0.01) than a seven year old sample.

TABLE XXXII

DUNCAN'S NEW MULTIPLE RANGE TEST FOR RIGHT KNEE EXTENSION OF MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range		
N	43	40	33	40	48	36	37	31	33			
Mean	43.72	52.57	63.9	69.52	78.24	84.1	87.27	113.12	119.9			
											df120	df ∞
7		8.85	*	*	*	*	*	*	*	R_2	75.29	72.1
8			11.33	*	*	*	*	*	*	R_3	76.26	75.07
9				5.62	*	*	*	*	*	R_4	78.44	77.25
10					8.72	*	*	*	*	R_5	80.03	78.64
11						5.89	9.03	*	*	R_6	81.22	80.03
12							3.14	*	*	R_7	82.21	81.02
13								*	*	R_8	83.20	81.81
14									*	R_9	83.79	82.6

* = difference in means significant beyond the 0.01 level of confidence

TABLE XXXIII

DUNCAN'S NEW MULTIPLE RANGE TEST FOR LEFT KNEE EXTENSION OF MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range		
N	43	40	33	40	48	36	37	31	33			
Mean	42.0	50.84	62.84	67.17	77.35	83.8	86.27	105.7	118.57			
											df120	df ∞
7		8.84	*	*	*	*	*	*	*	R_2	69.56	68.43
8			*	*	*	*	*	*	*	R_3	72.38	71.25
9				4.33	*	*	*	*	*	R_4	74.44	73.32
10					10.18	*	*	*	*	R_5	75.95	74.63
11						6.45	8.92	*	*	R_6	77.08	75.95
12							2.47	*	*	R_7	78.02	76.89
13								*	*	R_8	78.96	77.64
14									*	R_9	79.52	78.39

* = difference in means significant beyond the 0.01 level of confidence

Table XXXIV shows the results of Duncan's New Multiple Range test for leg lift strength of male samples. The fifteen year sample was stronger in leg lift than all age samples below that age. The mean differences in favor of the fifteen year old sample were all statistically significant at better than the 0.01 level of confidence. The mean differences resulted in Duncan Range scores that were greater than the shortest significant range level of 284.9 at df 120. Samples age fourteen, thirteen, twelve, elven, ten and eight resulted in leg lift scores that were not statistically significantly greater than the age sample of the age one below, but were significantly greater than all other ages below them by greater than one year. The nine year old sample was not stronger in the leg lift to a degree where statistical significance was reached.

Table XXXV shows the results of the Duncan's Multiple Range test for back lift strength. Ages fourteen, twelve, eleven, and eight years were statistically greater in strength in this parameter than all younger age samples. A mean difference of 15.56 pounds between the fifteen year sample and the fourteen year sample did not result in a Duncan score that reached the level of the shortest significant range, while the fifteen year old group was statistically greater in back lift strength over all other younger ages. The age thirteen and ten year samples, as well, did not surpass the mean strength of the next younger age group, while they did for the rest of the younger ages. The eight year old male sample was not significantly greater in this parameter over the seven year old sample.

TABLE XXXIV

DUNCAN'S NEW MULTIPLE RANGE TEST FOR LEG LIFT STRENGTH OF MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range		
N	43	40	33	40	48	36	37	31	33			
Means	115.72	145.5	194.4	213.5	248.3	285.7	324.5	364.6	427.4			
											df120	df ∞
7		29.83	*	*	*	*	*	*	*	R_2	284.9	280.3
8			*	*	*	*	*	*	*	R_3	296.48	291.86
9				19.07	*	*	*	*	*	R_4	304.95	300.33
10					34.87	*	*	*	*	R_5	311.12	305.72
11						37.38	*	*	*	R_6	315.74	311.12
12							38.79	*	*	R_7	319.59	413.97
13								40.11	*	R_8	323.44	318.05
14									*	R_9	325.75	321.13

* = difference in means significant beyond the 0.01 level of confidence

TABLE XXXV

DUNCAN'S NEW MULTIPLE RANGE TEST FOR BACK LIFT STRENGTH OF MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range		
N	43	40	33	40	48	36	37	31	33			
Means	73.13	80.82	103.6	106.8	121.6	144.3	157.7	199.3	215.0			
											df120	df ∞
7		7.69	*	*	*	*	*	*	*	R_2	97.27	95.69
8			*	*	*	*	*	*	*	R_3	101.2	99.63
9				3.14	*	*	*	*	*	R_4	104.1	102.5
10					*	*	*	*	*	R_5	106.2	104.3
11						*	*	*	*	R_6	107.7	106.2
12							13.34	*	*	R_7	109.1	107.5
13								*	*	R_8	110.4	108.5
14									15.56	R_9	111.2	109.6

* = difference in means significant beyond the 0.01 level of confidence

Analysis of the Age Differences in Strength for the Female Samples

Table XXXVI is a summary of the F test carried out on all parameters for the female samples. The means of each parameter were found to be statistically different at the 0.01 level of confidence, using the F-ratio test. The resulting F-ratio scores ranged from 20.45 to 169.27. This means that the null hypothesis with respect to the tests does not hold true and must, therefore be rejected. The F-ratio test supports the alternative hypothesis that a real difference does exist between the nine means of each parameter.

Now that a real difference has been shown to occur between means, it must be determined where this significance lies. Duncan's New Multiple Range test (25:136) was used to determine specifically this unknown. The result is the analysis of age differences for the female samples. This age difference analysis appears in Tables XXXVII through to XLVI.

The Duncan's New Multiple Range test for grip strength of female samples showed the following results. Age thirteen and age eleven samples, for both right and left grip, were significantly greater ($\alpha=0.01$) over all age samples of younger ages. That is, the differences in means were all above the Shortest Significant Ranges, which for R_2 equals 26.75 (df 120) for right grip, and 24.6 (df 120) for left grip. The mean differences were treated for unequal n's by the method of Kramer (1956). For left grip only, the twelve year and the nine year sample were statistically significantly greater than all younger ages. It was found that for right grip of fifteen, fourteen, twelve, ten, nine and eight year samples the mean differences in grip scores with the age sample just below the sample's age were not statistically significant. This was true also for left grip, with the exception of the twelve and nine year sample as noted above.

TABLE XXXVI
SUMMARY OF THE F TEST FOR ALL PARAMETERS OF THE FEMALE SAMPLES

Source of Variation	Sum of Squares	df	Mean Square	F
1. Right Grip Strength				
Among Means of Conditions	46885.11	8	5860.63	111.98*
Within Means	17740.36	339	52.33	
		347		
2. Left Grip Strength				
Among Means of Conditions	38021.57	8	4752.69	107.28*
Within Means	15019.3	339	44.3	
		347		
3. Elbow Flexion Right				
Among Means of Conditions	9783.57	8	1222.94	20.62*
Within Means	20101.76	339	59.29	
		347		
4. Elbow Flexion Left				
Among Means of Conditions	21056.07	8	2632.0	41.91*
Within Means	21287.27	339	62.79	
		347		
5. Right Elbow Extension				
Among Means of Conditions	18147.03	8	2268.37	41.07*
Within Means	18725.23	339	55.23	
		347		

* F score significant beyond the 0.01 level of confidence
(a α 0.01 F for 200 df = 2.60; F for 400 df = 2.55)

TABLE XXXVI (cont'd.)
SUMMARY OF THE F TEST FOR ALL PARAMETERS OF THE FEMALE SAMPLE

Source of Variation	Sum of Squares	df	Mean Square	F
6. Left Elbow Extension				
Among Means of Conditions	18081.69	8	22601.21	47.61*
Within Means	16092.71	339	47.47	
		347		
7. Right Knee Extension				
Among Means of Conditions	74793.34	8	9349.16	28.86*
Within Means	109804.37	339	323.9	
		347		
8. Left Knee Extension				
Among Means of Conditions	67940.08	8	8492.51	169.27*
Within Means	17009.91	339	50.17	
		347		
9. Leg Lift Strength				
Among Means of Conditions	954435.24	8	119304.4	20.45*
Within Means	1977240.08	339	5832.56	
		347		
10. Back Lift Strength				
Among Means of Conditions	266704.42	8	33805.2	71.07*
Within Means	161236.74	339	475.62	
		347		

* F score significant beyond the 0.01 level of confidence

TABLE XXXVII
DUNCAN'S NEW MULTIPLE RANGE TEST FOR RIGHT GRIP STRENGTH OF FEMALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range		
N	36	43	45	46	43	41	32	32	30			
Means	26.61	28.67	32.53	35.71	43.25	46.87	54.03	57.26	61.83			
											df120	df ∞
7		2.06	*	*	*	*	*	*	*	R_2	26.75	26.31
8			3.86	*	*	*	*	*	*	R_3	27.83	27.4
9				3.18	*	*	*	*	*	R_4	28.63	28.19
10					*	*	*	*	*	R_5	29.2	28.7
11						3.62	*	*	*	R_6	29.64	29.2
12							*	*	*	R_7	30.0	29.57
13								3.22	*	R_8	30.36	29.85
14									4.58	R_9	30.58	30.14

* = difference in means significant beyond the 0.01 level of confidence

TABLE XXXVIII
DUNCAN'S NEW MULTIPLE RANGE TEST FOR LEFT GRIP STRENGTH OF FEMALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range		
N	36	43	45	46	43	41	32	32	30			
Means	25.08	27.13	30.86	33.93	40.62	44.7	51.4	54.78	59.03			
											df120	df ∞
7		2.05	*	*	*	*	*	*	*	R_2	24.6	24.2
8			*	*	*	*	*	*	*	R_3	25.6	25.2
9				3.07	*	*	*	*	*	R_4	26.33	25.93
10					*	*	*	*	*	R_5	26.86	26.4
11						*	*	*	*	R_6	27.26	26.86
12							*	*	*	R_7	27.59	27.19
13								3.38	*	R_8	27.93	27.46
14									4.25	R_9	28.12	27.73

* = difference in means significant beyond the 0.01 level of confidence

Table XXXIX shows where significance lies for the right elbow flexion mean strength scores among female samples. As was shown in Figures V through to XII, female samples tested did not advance uniformly in mean strength as successive chronological years passed. Thus, we find that thirteen year old sample scores are above those of all other ages for certain test parameters.

A fifteen year old sample tested was not statistically stronger than thirteen year old girls, although they were statistically stronger ($\alpha = 0.01$) than all other ages tested. While thirteen year old girls were stronger (statistically significant at α 0.01) than fourteen year old girls as well as eleven, ten, nine, eight, and seven year old girls, they were not statistically stronger than twelve year old girls. The twelve year old sample tested had larger mean elbow flexion scores than the eleven and the fourteen year sample. However, mean differences of 3.31 and 3.71 pounds respectively, did not meet significance requirements for the 0.01 level of confidence. Twelve year sample mean scores were above ten, nine, eight, and seven year sample scores, and these differences were statistically significant ($\alpha = 0.01$). Eleven year mean elbow flexion scores were slightly greater than the fourteen year sample (mean difference = 0.40 pounds) but were not near significance; while the eleven year sample was stronger than the ten, nine, eight, and seven year samples - these mean differences being statistically significant. The age fourteen sample was stronger than the ten, nine, eight, and seven year samples, the difference in means being significant ($\alpha = 0.01$) in all cases. The age ten sample was also stronger than all younger age samples (significant at $\alpha = 0.01$). There were no significant differences between age nine, eight, and seven samples.

Table XL shows the left elbow flexion strength for the female samples. The results of this test were not similar with the right elbow flexion scores. The following results were found for the age difference analysis of left elbow flexion. The age fifteen sample had larger mean scores than all younger age samples. The mean differences were not statistically significant for age fifteen versus age thirteen and twelve, but were for all other younger ages. Age thirteen mean flexion scores were not statistically significant over age twelve, but were for all other younger ages, as well as the age fourteen sample. Age twelves were stronger ($\alpha = 0.01$) than age ten, nine, eight, and seven year samples, but were not stronger than eleven from the standpoint of statistical significance. The mean difference between age twelve and fourteen samples was 1.82 pounds in favor of the twelve year old, but this difference was not large enough to reach significance statistically. Statistical differences in favor of the age fourteen sample were found over the ten, nine, eight, and seven year samples. The eleven and ten year samples were not statistically greater than the younger age groups, but were for all other younger ages. The age nine sample was stronger on left elbow flexion over the eight and seven year sample ($\alpha = 0.01$). Similar to right elbow flexion, the eight year sample was not stronger than the seven year sample.

TABLE XXXIX

DUNCAN'S NEW MULTIPLE RANGE TEST FOR RIGHT ELBOW FLEXION STRENGTH OF FEMALE SAMPLES

Age	7	8	9	10	14	11	12	13	15	Shortest Significant Range		
N	36	43	45	46	32	43	41	32	30			
Means	24.5	25.48	28.91	33.36	39.43	39.83	43.13	47.56	48.7		df120	df ∞
7		0.98	4.41	*	*	*	*	*	*	R_2	28.49	28.02
8			3.43	*	*	*	*	*	*	R_3	29.64	29.18
9				*	*	*	*	*	*	R_4	30.49	30.03
10					*	*	*	*	*	R_5	31.1	30.56
14						0.40	3.71	*	*	R_6	31.57	31.1
11							3.31	*	*	R_7	31.95	31.49
12								4.42	*	R_8	32.34	31.8
13									1.14	R_9	32.57	32.1

* = difference in means significant beyond the 0.01 level of confidence

TABLE XL

DUNCAN'S NEW MULTIPLE RANGE TEST FOR LEFT ELBOW FLEXION STRENGTH OF FEMALE SAMPLES

Age	7	8	9	10	11	14	12	13	15	Shortest Significant Range		
N	36	43	45	46	43	32	41	32	30			
Means	23.97	25.44	30.4	34.39	38.67	40.59	42.41	46.46	46.6		df120	df ∞
7		1.47	*	*	*	*	*	*	*	R_2	29.19	28.71
8			*	*	*	*	*	*	*	R_3	30.37	29.9
9				3.97	*	*	*	*	*	R_4	31.24	30.77
10					4.28	*	*	*	*	R_5	31.87	31.32
11						1.92	3.74	*	*	R_6	32.34	31.87
14							1.82	*	*	R_7	32.74	32.27
12								4.05	4.19	R_8	33.13	32.58
13									0.14	R_9	33.37	32.9

* = difference in means significant beyond the 0.01 level of confidence

Table XLI includes the right elbow extension test results as they pertain to age differences. For this parameter the thirteen year sample had the highest mean scores. The thirteen year mean difference over the fifteen, twelve, and fourteen year samples were not great enough to reach the level of statistical significance ($\alpha = 0.01$). The differences with all other age samples were statistically significant in favor of the thirteen year olds. The mean extension strength that was next highest for females was for the fifteen year old sample. The mean differences over twelve and fourteen year olds were not statistically significant, but were for all other younger ages, with the exception noted above. Mean differences in favor of the twelve year old sample over fourteen and elven year olds were not significant, but were for twelves over younger ages from ten down. The age fourteen sample was not statistically significantly stronger than the eleven year sample; though they were for ages ten and less. Age eleven were stronger than all other younger ages ($\alpha = 0.01$). Age ten and nine samples were significantly stronger for ages two years younger than them. Age eights were not significantly stronger than age sevens.

While the left elbow extension strength scores fell in the same order as the right side scores, there were the following differences. The age thirteen sample was significantly stronger than all other age samples tested - with one exception - which was the fifteen year old sample. A mean difference of 3.16 pounds in favor of the thirteen year sample was below significance. The age fifteen sample followed the identical pattern established by the right extension scores. For left elbow extension the age twelve sample was significantly stronger

TABLE XLI

DUNCAN'S NEW MULTIPLE RANGE TEST FOR RIGHT ELBOW EXTENSION OF FEMALE SAMPLES

Age	7	8	9	10	11	14	12	15	13	Shortest Significant Range		
N	36	43	45	46	43	32	41	30	32			
Means	19.88	21.72	24.4	27.58	33.09	35.81	36.65	39.96	40.62			
											df120	df ∞
7		1.84	*	*	*	*	*	*	*	R_2	27.49	27.04
8			2.78	*	*	*	*	*	*	R_3	28.6	28.15
9				3.18	*	*	*	*	*	R_4	29.42	28.97
10					*	*	*	*	*	R_5	30.01	29.49
11						2.72	3.56	*	*	R_6	30.46	30.01
14							0.84	4.15	4.81	R_7	30.83	30.38
12								3.31	3.97	R_8	31.2	30.68
15									0.66	R_9	31.42	30.98

* = difference in means significant beyond the 0.01 level of confidence

TABLE XLII

DUNCAN'S NEW MULTIPLE RANGE TEST FOR LEFT ELBOW EXTENSION OF FEMALE SAMPLES

Age	7	8	9	10	11	14	12	15	13	Shortest Significant Range		
N	36	43	45	46	43	32	41	30	32			
Means	20.41	21.3	24.83	27.26	31.53	35.46	35.82	39.3	42.46			
											df120	df ∞
7		0.89	*	*	*	*	*	*	*	R_2	25.45	25.04
8			3.58	*	*	*	*	*	*	R_3	26.48	26.07
9				2.38	*	*	*	*	*	R_4	27.24	26.83
10					*	*	*	*	*	R_5	27.79	27.31
11						3.93	*	*	*	R_6	28.2	27.79
14							0.36	3.84	*	R_7	28.55	28.13
12								3.48	*	R_8	28.89	28.41
15									3.16	R_9	29.1	28.68

* = difference in means significant beyond the 0.01 level of confidence

than the eleven year sample. The age fourteen sample followed the pattern established for the right extension scores, as did the eleven, ten, nine, eight, and seven year samples.

Duncan's New Multiple Range test resulted in the following age analysis for right knee extension strength. The thirteen year old sample again scored the highest mean strength. Although the mean difference in strength was in their favor over the fifteen, twelve and fourteen year samples, these differences failed to be significant at the 0.01 level of confidence. Mean differences in favor of the thirteen year sample that resulted in significance were found over the eleven, ten, nine, eight, and seven year samples. Fifteen year olds were significantly stronger than the ten, nine, eight, and seven year samples only. While twelve year olds showed greater mean strength than both fourteen and eleven year samples these differences did not reach significance statistically. Significant differences were found between twelve year olds and all other younger ages. The fourteen year old sample was not significantly stronger over the eleven year sample. The mean differences between age ten, nine and eight samples and all of their respective younger ages took the pattern of non-significance with the next youngest age; and statistical significance with the rest of the younger ages.

For left knee extension the following differences were found. Thirteen year olds, the strongest group, were statistically significantly stronger than all other age samples of females. Fifteen year olds, the second strongest group, were also significantly stronger than all other age groups below them in mean strength. Twelve year olds, whose mean strength was greater than fourteen year olds, were significantly stronger than all

TABLE XLIII

DUNCAN'S NEW MULTIPLE RANGE TEST FOR RIGHT KNEE EXTENSION OF FEMALE SAMPLES

Age	7	8	9	10	11	14	12	15	13	Shortest Significant Range		
N	36	43	45	46	43	32	41	30	32			
Means	46.77	51.02	61.16	68.95	75.39	81.37	83.31	85.8	92.53			
											df120	df ∞
7		4.25	*	*	*	*	*	*	*	R_2	66.56	65.48
8			10.13	*	*	*	*	*	*	R_3	69.26	68.18
9				7.80	*	*	*	*	*	R_4	71.24	70.16
10					6.44	*	*	*	*	R_5	72.67	71.42
11						5.98	7.92	10.41	*	R_6	73.75	72.67
14							1.94	4.43	11.16	R_7	74.65	73.57
12								2.49	9.22	R_8	75.55	74.29
15									6.73	R_9	76.09	75.01

* = difference in means significant beyond the 0.01 level of confidence

TABLE XLIV

DUNCAN'S NEW MULTIPLE RANGE TEST FOR LEFT KNEE EXTENSION OF FEMALE SAMPLES

Age	7	8	9	10	11	14	12	15	13	Shortest Significant Range		
N	36	43	45	46	43	32	41	30	32			
Means	46.52	49.02	63.31	63.8	72.8	77.99	80.41	85.39	90.9			
											df120	df ∞
7		2.5	*	*	*	*	*	*	*	R_2	26.14	25.77
8			*	*	*	*	*	*	*	R_3	27.25	26.83
9				*	*	*	*	*	*	R_4	28.03	27.61
10					*	*	*	*	*	R_5	28.6	28.1
11						*	*	*	*	R_6	29.02	28.6
14							2.42	*	*	R_7	29.38	28.95
12								*	*	R_8	29.73	29.24
15									*	R_9	29.94	29.52

* = difference in means significant beyond the 0.01 level of confidence

other younger ages. The twelve year - fourteen year difference was not significant. The sample of fourteen year olds was significantly greater than samples of age eleven, ten, nine, eight, and seven years of age. For the samples of age eleven, ten, and nine statistically significant differences were found with all younger age samples. The eight year old sample was not significantly stronger than the seven year sample.

The Duncan's New Multiple Range test for leg lift strength of female samples resulted in some of the following findings. The fifteen year old sample was the strongest in this parameter. The fourteen year old sample had a mean leg lift score between that of the eleven and ten year sample. There were only small and insignificant differences found between the fifteen, thirteen, and twelve year samples. While the fifteen year old sample exhibited mean differences over the eleven and fourteen year samples of 34.89 and 35.49 pounds respectively, these differences were below significance at the 0.01 level of confidence. The only significant differences found were for the fifteens over the ten and younger age groups. The thirteens were significantly greater than these groups also. The eleven year sample were statistically significantly greater than the nine and under samples. The only statistically significant differences in favor of the fourteen year sample were found over the nine, eight and seven year samples. Ten year olds were significantly greater than eight and seven year olds. The age nine mean difference in favor of them, over the eight and seven year samples were both statistically significant. The eights and sevens were not significantly different.

The age analysis for the strength of back lift resulted in the following findings. The age thirteen sample was the strongest in this

parameter. Although the fifteen, fourteen, and twelve year means were all lower than the thirteen year mean, they did not result in a statistically significant difference at the 0.01 level of confidence. Significant differences were found for all other younger ages. The fifteen year sample, the second largest mean score group, obtained statistically significant differences over samples of age eleven and younger. Samples of age eleven and under were significantly lower in back lift strength than the fourteen year group. The age twelve and eleven samples were significantly stronger than all ages younger than them. The ten year sample was not significantly stronger than the nine year olds, but was over the eight and sevens. Significant differences in favor of the nine year old sample was found over the eight and seven year groups. Seven and eight year samples did not differ significantly in strength.

TABLE XLV

DUNCAN'S NEW MULTIPLE RANGE TEST FOR LEG LIFT STRENGTH OF FEMALE SAMPLES

Age	7	8	9	10	14	11	12	13	15	Shortest Significant Range	
N	36	43	45	46	32	43	41	32	30		
Means	110.72	129.3	181.6	202.4	227.3	227.9	259.7	261.46	262.86		
										df120	df ∞
7		18.65	*	*	*	*	*	*	*	R_2 282.56	277.98
8			*	*	*	*	*	*	*	R_3 294.02	289.44
9				20.81	*	*	*	*	*	R_4 302.42	297.84
10					24.96	25.56	*	*	*	R_5 308.53	303.18
14						0.60	32.33	34.09	35.49	R_6 313.11	308.53
11							31.73	33.49	34.89	R_7 316.93	312.35
12								1.76	3.16	R_8 320.75	315.4
13									1.40	R_9 333.04	318.46

* = difference in means significant beyond the 0.01 level of confidence

TABLE XLVI

DUNCAN'S NEW MULTIPLE RANGE TEST FOR BACK LIFT STRENGTH OF FEMALES SAMPLES

Age	7	8	9	10	11	12	14	15	13	Shortest Significant Range	
N	36	43	45	46	43	41	32	30	32		
Means	66.63	71.32	85.62	94.65	113.65	128.6	136.09	141.96	142.71		
										df120	df ∞
7		4.69	*	*	*	*	*	*	*	R_2 80.66	79.35
8			*	*	*	*	*	*	*	R_3 83.93	82.62
9				3.67	*	*	*	*	*	R_4 86.32	85.02
10					*	*	*	*	*	R_5 88.07	86.54
11					*	*	*	*	*	R_6 89.38	88.07
12							7.46	13.33	14.07	R_7 90.47	89.16
14								5.87	6.61	R_8 91.56	90.03
15									0.74	R_9 92.21	90.90

* = difference in means significant beyond the 0.01 level of confidence

Sex Differences Occurring Among Age Samples.

Tables XLVII throuth LVI present an analysis of sex differences in the strength parameters, based on the t test outlined by Edwards (25:106-07). A previous homogeneity or heterogeneity test carried out indicated the ratio of the largest mean's variance to the smallest mean's variance. The appropriate table (25: Table IX) was then used to specify either homogeneity or heterogeneity. The t test was then carried out (25:107). The resulting t from homogeneous samples was used directly, while if heterogeneity was found, the resulting t score was adjusted by the method outlined by Edwards (25:107, Formula 8.2).

Significant differences in mean grip scores between sexes are shown in Tables XLVII and XLVIII. For right grip differences in means that were significant beyond the 0.01 level of confidence were found between samples of eight, nine, ten, fourteen and fifteen year olds. All of these mean differences were in favor of the male samples. Identical results insofar as significance is concerned were found with left grip strength.

Elbow flexion strength was found to differ significantly between sexes of the same age at thirteen, fourteen, and fifteen years of age, both for right and left elbow flexion strength. For right elbow flexion only there were statistically significant differences between means at age eight and nine samples for the two sexes.

Elbow extension strength was analyzed by the same procedure in Tables LI and LII. There were found to be statistically significant sex differences for both right and left strength at ages eight, fourteen, and fifteen.

c. Differences according to Area and Region.

Tables XLVII through LVI present an analysis of the differences in the strength parameters, based on the t test outlined by Edwards (25:199-207). A previous homogeneity or heterogeneity test involved the formation of the ratio of the largest sample variance to the smallest sample variance. The appropriate table (25: Table II) was then used to specify either homogeneity or heterogeneity. The t test was then carried out (25:205). The formula of t from homogeneous samples was used directly, while if heterogeneity was found, the resulting t score was adjusted by the method outlined by Edwards (25:207, formula 9.4).

Significant differences in mean grip scores between areas are shown in Tables XLVII and XLVIII. For right grip differences in means that were significant beyond the 0.05 level of confidence were found between samples of eight, nine, ten, fourteen and fifteen year olds. All of these mean differences were in favor of the male samples. Individual results indicated no significance in comparison with left grip strength.

Elbow flexion strength was found to differ significantly between means at the same age at eighteen, fourteen, and fifteen years of age both for right and left elbow flexion strength. For right elbow flexion there were statistically significant differences between means of the eight and nine samples for the two areas.

Elbow extension strength was compared by the same procedure in Tables LI and LII. There were found to be statistically significant differences for both right and left strength at ages eight, fourteen, and fifteen.

For right side extension there were found in addition statistically significant differences between the sexes at ages nine and ten. As for elbow flexion strength, greater differences in strength were found between sexes for right strength among younger ages. Differences in these strengths did not occur as readily between sexes for left body scores at the younger ages.

Knee extension strength tests showed no statistically significant sex differences until age fourteen. The age fourteen and fifteen differences were both in favor of the males. The results indicated that females were stronger than males more often in this parameter then they were in any other. For left knee extension strength females were superior in mean strength at ages seven, nine, ten, and thirteen, however none of these differences reached statistical significance.

Leg lift strength differed significantly at ages thirteen, fourteen, and fifteen all in favor of male samples. A t score of 1.82 at age eight did not reach significance.

Back lift strength showed much stronger differences between sexes than did leg lift strength. Differences in means that were statistically significant occurred at ages eight, nine, ten, fourteen and fifteen, all in favor of the male samples.

TABLE XLVII

ANALYSIS OF SEX DIFFERENCES FOR RIGHT GRIP STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	28.06	26.61	77	2.641	1.34	Male
8	32.85	28.67	81	2.638	3.42*	Male
9	37.72	32.53	76	2.642	3.43*	Male
10	42.72	35.71	84	2.703	3.54*	Male
11	43.27	43.25	89	2.633	0.001	Male
12	51.58	46.87	75	2.643	2.23	Male
13	55.54	54.03	67	2.651	0.62	Male
14	75.93	57.25	61	2.65	7.47*	Male
15	32.63	61.83	61	2.65	5.81*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE XLVIII

ANALYSIS OF SEX DIFFERENCES FOR LEFT GRIP STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	26.83	25.08	77	2.64	1.59	Male
8	31.37	27.13	81	2.63	3.71*	Male
9	36.27	30.86	75	2.64	3.55*	Male
10	40.62	33.93	84	2.63	6.69*	Male
11	41.16	40.62	89	2.63	0.33	Male
12	49.69	44.70	75	2.64	2.19	Male
13	53.94	51.40	67	2.65	1.25	Male
14	73.87	54.78	61	2.65	8.02*	Male
15	82.72	59.03	61	2.73	8.03*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE XLIX

ANALYSIS OF SEX DIFFERENCES FOR RIGHT ELBOW FLEXION STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	24.11	24.50	77	2.64	0.30	Female
8	28.67	25.48	81	2.63	2.79*	Male
9	33.12	28.91	76	2.64	2.82*	Male
10	36.69	33.36	84	2.63	2.14	Male
11	39.60	39.83	89	2.63	0.12	Female
12	48.44	43.14	75	2.64	2.07	Male
13	55.64	47.56	67	2.65	2.85*	Male
14	67.51	39.43	61	2.74	7.42*	Male
15	77.06	48.70	61	2.73	7.76*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE L

ANALYSIS OF SEX DIFFERENCES FOR LEFT ELBOW FLEXION STRENGTH BY THE TEST METHOD

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	25.00	23.97	77	2.64	1.67	Male
8	28.07	25.44	81	2.63	2.24	Male
9	33.51	30.42	76	2.64	1.82	Male
10	35.87	34.39	84	2.63	0.93	Male
11	39.06	38.67	89	2.63	0.21	Male
12	48.33	42.41	75	2.64	2.24	Male
13	54.83	46.46	67	2.71	3.04*	Male
14	65.41	40.59	61	2.65	7.05*	Male
15	73.50	46.60	61	2.73	7.45*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE LI

ANALYSIS OF SEX DIFFERENCES FOR RIGHT ELBOW EXTENSION STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	21.46	19.88	77	2.64	1.62	Male
8	25.4	21.72	81	2.63	3.83*	Male
9	28.0	24.4	76	2.64	5.12*	Male
10	31.85	27.58	84	2.63	3.5 *	Male
11	33.7	33.09	89	2.63	0.43	Male
12	38.72	36.65	75	2.64	0.91	Male
13	43.35	40.62	67	2.65	1.05	Male
14	56.8	35.81	61	2.74	7.66*	Male
15	65.36	39.96	61	2.73	7.22*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE LII

ANALYSIS OF SEX DIFFERENCES FOR LEFT ELBOW EXTENSION STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	21.79	20.41	77	2.64	1.26	Male
8	24.62	21.3	81	2.63	3.68*	Male
9	26.66	24.88	76	2.64	1.41	Male
10	29.92	27.26	84	2.63	2.35	Male
11	34.06	31.53	89	2.63	1.90	Male
12	38.94	35.82	75	2.64	1.55	Male
13	44.16	42.46	67	2.65	0.58	Male
14	55.67	35.46	61	2.74	6.73*	Male
15	64.24	39.3	61	2.73	7.67*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE LIII

ANALYSIS OF SEX DIFFERENCES FOR RIGHT KNEE EXTENSION STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	43.72	46.77	77	2.64	1.21	Female
8	52.57	51.02	81	2.63	0.59	Male
9	63.90	61.15	76	2.64	0.8	Male
10	69.52	68.95	34	2.63	0.17	Male
11	78.24	75.39	89	2.63	0.72	Male
12	84.13	83.13	75	2.64	0.20	Male
13	87.27	92.53	67	2.65	1.02	Female
14	113.12	81.37	61	2.65	5.31*	Male
15	119.96	85.8	61	2.65	4.74*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE LIV

ANALYSIS OF SEX DIFFERENCES FOR LEFT KNEE EXTENSION STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	42.00	46.52	77	2.64	1.77	Female
8	50.84	49.02	81	2.63	0.68	Male
9	62.84	63.31	76	3.64	0.12	Female
10	67.17	68.8	84	2.63	0.49	Female
11	77.35	72.8	89	2.63	1.12	Male
12	83.8	80.41	75	2.64	0.65	Male
13	86.27	90.9	67	2.65	0.89	Female
14	105.7	77.99	61	2.65	5.33*	Male
15	118.57	85.39	61	2.65	6.45*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE LV

ANALYSIS OF SEX DIFFERENCE FOR LEG LIFT STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	115.72	110.72	77	2.64	0.56	Male
8	145.55	129.37	81	2.63	1.82	Male
9	194.45	181.6	76	2.64	0.95	Male
10	213.52	202.41	84	2.63	0.89	Male
11	248.39	227.97	89	2.63	1.2	Male
12	285.77	259.70	75	2.64	1.08	Male
13	324.56	261.46	67	2.65	2.71*	Male
14	364.67	227.37	61	2.65	6.25*	Male
15	427.42	262.86	61	2.65	5.07*	Male

* difference in means significant beyond the 0.01 level of confidence

TABLE LVI

ANALYSIS OF SEX DIFFERENCES FOR BACK LIFT STRENGTH

Ages Compared	Male Mean	Female Mean	df	Critical t	t	Direction of t
7	73.13	66.63	77	2.64	1.64	Male
8	80.82	71.32	81	2.63	2.84*	Male
9	103.66	85.62	76	2.64	3.55*	Male
10	106.8	94.45	84	2.63	3.2 *	Male
11	121.64	113.65	89	2.63	1.69	Male
12	144.38	128.63	75	2.64	2.33	Male
13	157.72	142.71	67	2.65	2.16	Male
14	199.35	136.09	61	2.65	9.02*	Male
15	215.0	141.96	61	2.73	8.74*	Male

* difference in means significant beyond the 0.01 level of confidence

Correlations For All Parameters.

All parameters were subject to a computer calculation of zero order correlations. A t test was then carried out for a hypothesis of zero correlation. The method used for the t score calculation was that of Edwards (25:78). The test was a non-directional or two sided test of significance. The t scores calculated were tested for significance at both the 0.01 and the 0.05 level of confidence.

The results of this analysis are found in tables LVII through to LXXIV. Correlations between age, height, and weight are included as well as the ten strength parameters.

Dextrality coefficients for right to left hand grip strength of the male samples were all significantly different from zero at the 0.01 level of confidence. These correlations ranged from 0.81 to 0.91. Female correlations were also all significantly different from zero at the 0.01 level of confidence. The correlations were lower ranging from 0.65 to 0.86.

The correlations between the right and left sides of the body for elbow flexion, elbow extension, and knee extension were, with only one exception, significantly different from zero at the 0.01 level of confidence. These correlations ranged between 0.63 and 0.93. The one exception was a correlation of 0.44 between elbow extension right and left at age fifteen. This correlation was significantly different from zero at the 0.05 level of confidence.

The leg lift to back lift correlations for males ranged from 0.34 to 0.64. Three of these correlations were significantly different from zero at the 0.05 level of confidence, while the rest were significant at

Correlations of All Parameters.

All parameters were entered in a computer calculation of zero order correlations. A t test was then carried out for a significance of these correlations. The method used for the t score calculation was that of Edwards ([illegible]). The test was a two-tailed test [illegible] level of significance. The t scores obtained were compared for significance at both the 0.05 and the 0.01 level of confidence.

The results of this analysis are shown in tables [illegible] through [illegible]. Correlations between age, height, and weight are included as well as the two strength parameters.

Laterality coefficients for right to left hand grip strength of the male subjects were all significantly different from zero at the 0.[illegible] level of confidence. These correlations ranged from [illegible] to [illegible]. Female correlations were also all significantly different from zero at the 0.01 level of confidence. The correlation coefficients ranged from [illegible] to [illegible].

The correlations between the right and left sides of the body for elbow flexion, elbow extension, and knee extension were, with only one exception, significantly different from zero at the 0.01 level of confidence. These correlations ranged between [illegible] and [illegible]. The one exception was a correlation of [illegible] between elbow extension right and left at age fifteen. This correlation was significantly different from zero at the 0.05 level of confidence.

The [illegible] of knee flexion correlations the values ranged from [illegible] to [illegible]. Three of these correlations were significantly different from zero at the 0.05 level of confidence, while the others were significant

the 0.01 level. One of the correlations between leg lift and back lift was not significantly different from zero. This correlation was 0.23 which was below the required critical t of 0.28 for age ten females. The commonality for these correlations ranged between 12 percent and 41 percent.

Height and weight correlated in the range of 0.44 to 0.74 for the male samples. These were all significant at the 0.01 level of confidence with the exception of 0.44 which was significantly different from zero at the 0.05 level of confidence. Female means resulted in correlations of 0.19 (not significant) to 0.87. All of the female correlations(except the 0.19) were significant at the 0.01 level of confidence. The correlation of 0.19 was for the age fifteen females.

The correlations between height and right grip strength were mostly significantly different from zero at the 0.01 level of confidence. Three of them were significant at the 0.05 level of confidence. The correlation for age fourteen males was only 0.03, far from being significantly different over zero. For females the correlations were lower with significance reached for ages between age ten and fourteen. The lower age females did not have right grip and height correlation scores that were significantly different from zero.

The correlations for right grip strength with weight among males were significantly different from zero at all ages but eleven. For females the correlations were not significant at ages eight and fifteen. The correlations were not high.

TABLE LVII

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE SEVEN MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	-0.04	-0.04	-0.04	0.06	0.13	0.09	0.08	-0.00	0.29**	0.21	0.05	0.19
HEIGHT		0.70*	0.54*	0.59*	0.27	0.30**	0.20	0.32**	0.29**	0.32**	0.34**	0.45**
WEIGHT			0.39*	0.42*	0.32**	0.31**	0.27	0.43*	0.15	0.41*	0.31**	0.47*
RIGHT GRIP				0.85*	0.51*	0.35**	0.30**	0.31**	0.45*	0.35**	0.54*	0.48*
LEFT GRIP					0.57*	0.48*	0.25	0.34**	0.49*	0.41*	0.52*	0.59*
ELBOW FLEXION RIGHT						0.75*	0.54*	0.52*	0.61*	0.67*	0.61*	0.60*
ELBOW FLEXION LEFT							0.57*	0.57*	0.40*	0.53*	0.43*	0.51*
ELBOW EXTENSION RIGHT								0.71*	0.46*	0.55*	0.40*	0.40*
ELBOW EXTENSION LEFT									0.40*	0.57*	0.44*	0.57*
KNEE EXTENSION RIGHT										0.75*	0.68*	0.55*
KNEE EXTENSION LEFT											0.52*	0.63*
LEG LIFT												0.57*

* Critical t of 2.70 at the 0.01 level of confidence
** Critical t of 2.01 at the 0.05 level of confidence

TABLE LVIII

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE EIGHT MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.25	0.12	0.34**	0.25	0.08	0.06	0.24	0.17	0.07	0.25	0.28	0.25
HEIGHT		0.50*	0.43*	0.34**	0.14	0.26	0.34**	0.31**	0.14	0.13	0.29	0.21
WEIGHT			0.55*	0.52*	0.17	0.11	0.30**	0.36**	0.31**	0.16	0.28	0.46*
RIGHT GRIP				0.89*	0.48*	0.53*	0.46*	0.51*	0.31**	0.44*	0.55*	0.56*
LEFT GRIP					0.51*	0.49*	0.39**	0.44*	0.38**	0.45*	0.54*	0.52*
ELBOW FLEXION RIGHT						0.86*	0.44*	0.60*	0.43*	0.45*	0.47*	0.52*
ELBOW FLEXION LEFT							0.48*	0.56*	0.36**	0.41*	0.53*	0.48*
ELBOW EXTENSION RIGHT								0.78*	0.39**	0.45*	0.60*	0.70*
ELBOW EXTENSION LEFT									0.42*	0.59*	0.53*	0.67*
KNEE EXTENSION RIGHT										0.74*	0.57*	0.36**
KNEE EXTENSION LEFT											0.57*	0.45*
LEG LIFT												0.64*

* Critical t of 2.71 at the 0.01 level of confidence
** Critical t of 2.02 at the 0.05 level of confidence

TABLE LIX

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE NINE MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.47*	0.37**	0.38**	0.41**	0.26	0.19	0.33**	0.23	0.29	0.46*	0.14	0.48*
HEIGHT		0.72*	0.35**	0.42**	0.36**	0.32	0.30	0.37**	0.25	0.36**	0.33**	0.49*
WEIGHT			0.59*	0.63*	0.62*	0.56*	0.42**	0.56*	0.38**	0.42**	0.46*	0.51*
RIGHT GRIP				0.85*	0.48*	0.53*	0.48*	0.56*	0.41**	0.46*	0.23	0.42**
LEFT GRIP					0.49*	0.52*	0.40**	0.49*	0.41**	0.39**	0.27*	0.41**
ELBOW FLEXION RIGHT						0.77*	0.52*	0.56*	0.45*	0.32	0.32	0.53*
ELBOW FLEXION LEFT							0.63*	0.66*	0.43*	0.30	0.38**	0.46*
ELBOW EXTENSION RIGHT								0.85*	0.65*	0.46*	0.47*	0.50*
ELBOW EXTENSION LEFT									0.59*	0.48*	0.55*	0.47*
KNEE EXTENSION RIGHT										0.77*	0.54*	0.46*
KNEE EXTENSION LEFT											0.63*	0.44*
LEG LIFT												0.36**

* Critical t of 2.74 at the 0.01 level of confidence
** Critical t of 2.03 at the 0.05 level of confidence

TABLE LX

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE TEN MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.11	0.06	-0.05	-0.05	0.13	0.18	0.25	0.24	0.25	0.11	0.26	0.16
HEIGHT		0.72*	0.35**	0.36**	0.36**	0.48*	0.51*	0.40*	0.19	0.17	0.26	0.36**
WEIGHT			0.64*	0.65*	0.52*	0.66*	0.77*	0.71*	0.37**	0.34**	0.35**	0.41*
RIGHT GRIP				0.91*	0.47*	0.57*	0.66*	0.56*	0.38**	0.19	0.09	0.57*
LEFT GRIP					0.54*	0.61*	0.69*	0.66*	0.44*	0.27	0.16	0.58*
ELBOW FLEXION RIGHT						0.84*	0.72*	0.76*	0.53*	0.48*	0.49*	0.53*
ELBOW FLEXION LEFT							0.76*	0.76*	0.54*	0.42*	0.40*	0.61*
ELBOW EXTENSION RIGHT								0.88*	0.63*	0.53*	0.49*	0.59*
ELBOW EXTENSION LEFT									0.59*	0.47*	0.49*	0.58*
KNEE EXTENSION RIGHT										0.82*	0.61*	0.61*
KNEE EXTENSION LEFT											0.69*	0.49*
LEG LIFT												0.39**

* Critical t of 2.71 at the 0.01 level of confidence
** Critical t of 2.02 at the 0.05 level of confidence

TABLE LXI

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE ELEVEN MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.36*	0.09	-0.00	0.07	-0.08	0.03	-0.07	0.01	-0.10	-0.03	-0.13	-0.12
HEIGHT		0.44*	0.50*	0.54*	0.50*	0.43*	0.21	0.38*	0.24	0.18	0.10	0.41*
WEIGHT			0.23	0.17	0.29**	0.25	0.16	0.25	0.23	0.16	0.07	0.23
RIGHT GRIP				0.88*	0.56*	0.45*	0.50*	0.55*	0.31**	0.30**	0.30**	0.42*
LEFT GRIP					0.58*	0.51*	0.48*	0.65*	0.35**	0.35**	0.34**	0.43*
ELBOW FLEXION RIGHT						0.82*	0.64*	0.74*	0.64*	0.58*	0.51*	0.70*
ELBOW FLEXION LEFT							0.74*	0.78*	0.64*	0.59*	0.57*	0.66*
ELBOW EXTENSION RIGHT								0.78*	0.57*	0.59*	0.50*	0.61*
ELBOW EXTENSION LEFT									0.58*	0.63*	0.60*	0.64*
KNEE EXTENSION RIGHT										0.86*	0.63*	0.68*
KNEE EXTENSION LEFT											0.69*	0.66*
LEG LIFT												0.52*

* Critical t of 2.68 at the 0.01 level of confidence
** Critical t of 2.01 at the 0.05 level of confidence

TABLE LXII

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE TWELVE MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.17	0.30	-0.05	-0.03	0.29	0.21	0.09	0.13	0.12	0.07	-0.03	0.10
HEIGHT		0.74*	0.52*	0.49*	0.59*	0.61*	0.47*	0.47*	0.39**	0.40**	0.50*	0.60*
WEIGHT			0.44*	0.43*	0.51*	0.44*	0.41*	0.34**	0.48*	0.46*	0.42*	0.50*
RIGHT GRIP				0.86*	0.27	0.29	0.50*	0.46*	0.42*	0.39**	0.48*	0.71*
LEFT GRIP					0.43*	0.45*	0.60*	0.51*	0.42*	0.45*	0.68*	0.67*
ELBOW FLEXION RIGHT						0.88*	0.71*	0.67*	0.52*	0.64*	0.63*	0.59*
ELBOW FLEXION LEFT							0.75*	0.71*	0.52*	0.64*	0.69*	0.60*
ELBOW EXTENSION RIGHT								0.77*	0.44*	0.45*	0.69*	0.65*
ELBOW EXTENSION LEFT									0.38**	0.45*	0.59*	0.53*
KNEE EXTENSION RIGHT										0.85*	0.55*	0.56*
KNEE EXTENSION LEFT											0.66*	0.51*
LEG LIFT												0.52*

* Critical t of 2.72 at the 0.01 level of confidence
** Critical t of 2.01 at the 0.05 level of confidence

TABLE LXIII

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE THIRTEEN MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.40**	0.36**	0.41**	0.23	0.38**	0.41**	0.46*	0.45*	0.40**	0.27	0.47*	0.08
HEIGHT		0.74*	0.62*	0.54*	0.53*	0.62*	0.65*	0.67*	0.32	0.37**	0.32	0.58*
WEIGHT			0.53*	0.46*	0.60*	0.56*	0.56*	0.63*	0.44*	0.48*	0.31	0.48*
RIGHT GRIP				0.83*	0.67*	0.60*	0.71*	0.66*	0.65*	0.55*	0.47*	0.72*
LEFT GRIP					0.56*	0.53*	0.60*	0.60*	0.57*	0.54*	0.54*	0.67*
ELBOW FLEXION RIGHT						0.80*	0.71*	0.77*	0.71*	0.66*	0.57*	0.66*
ELBOW FLEXION LEFT							0.80*	0.85*	0.62*	0.61*	0.62*	0.64*
ELBOW EXTENSION RIGHT								0.92*	0.66*	0.58*	0.69*	0.62*
ELBOW EXTENSION LEFT									0.67*	0.57*	0.72*	0.63*
KNEE EXTENSION RIGHT										0.87*	0.67*	0.44*
KNEE EXTENSION LEFT											0.62*	0.40**
LEG LIFT												0.42**

TABLE LXIV

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE FOURTEEN MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	-0.23	-0.01	-0.03	0.02	0.07	0.05	-0.11	0.03	0.27	0.25	-0.21	-0.05
HEIGHT		0.40**	0.03	0.07	0.07	-0.11	0.16	-0.10	-0.02	-0.02	0.13	0.31
WEIGHT			0.57*	0.51*	0.44**	0.36**	0.64*	0.52*	0.18	0.26	-0.11	0.49*
RIGHT GRIP				0.84*	0.47*	0.40**	0.64*	0.69*	0.43**	0.51*	0.19	0.67*
LEFT GRIP					0.56*	0.51*	0.69*	0.75*	0.36**	0.47*	0.13	0.56*
ELBOW FLEXION RIGHT						0.89*	0.70*	0.81*	0.46**	0.44**	0.36**	0.62*
ELBOW FLEXION LEFT							0.66*	0.78*	0.40**	0.37**	0.26	0.46**
ELBOW EXTENSION RIGHT								0.84*	0.39**	0.46**	0.18	0.64*
ELBOW EXTENSION LEFT									0.42**	0.56*	0.26	0.60*
KNEE EXTENSION RIGHT										0.85*	0.60*	0.48*
KNEE EXTENSION LEFT											0.50*	0.40**
LEG LIFT												0.34**

* Critical t of 2.75 at the 0.01 level of confidence
** Critical t of 2.04 at the 0.05 level of confidence

TABLE LXV

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE FIFTEEN MALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.33**	0.35**	0.37**	0.31	0.44*	0.42**	0.36**	0.44*	0.12	0.18	0.23	0.31
HEIGHT		0.74*	0.40**	0.51*	0.63*	0.61*	0.66*	0.64*	0.59*	0.56*	0.31	0.51*
WEIGHT			0.49*	0.68*	0.71*	0.68*	0.71*	0.73*	0.66*	0.68*	0.31	0.59*
RIGHT GRIP				0.81*	0.61*	0.66*	0.39**	0.43*	0.37**	0.49*	0.54*	0.70*
LEFT GRIP					0.74*	0.68*	0.62*	0.66*	0.63*	0.68*	0.56*	0.82*
ELBOW FLEXION RIGHT						0.89*	0.79*	0.85*	0.73*	0.76*	0.63*	0.69*
ELBOW FLEXION LEFT							0.75*	0.85*	0.68*	0.73*	0.65*	0.70*
ELBOW EXTENSION RIGHT								0.88*	0.69*	0.64*	0.48*	0.59*
ELBOW EXTENSION LEFT									0.75*	0.71*	0.49*	0.66*
KNEE EXTENSION RIGHT										0.91*	0.51*	0.72*
KNEE EXTENSION LEFT											0.58*	0.75*
LEG LIFT												0.61*

* Critical t of 2.74 at the 0.01 level of confidence
** Critical t of 2.03 at the 0.05 level of confidence

TABLE LXVI

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE SEVEN FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.19	-0.03	0.34**	0.17	0.26	0.07	0.12	0.24	0.25	0.20	0.34**	0.14
HEIGHT		0.58*	0.38	0.50*	0.44*	0.29	0.53*	0.50*	0.60*	0.50*	0.53*	0.61*
WEIGHT			0.51*	0.69*	0.66*	0.61*	0.49*	0.51*	0.54*	0.54*	0.47*	0.55*
RIGHT GRIP				0.75*	0.64*	0.63*	0.61*	0.60*	0.48*	0.49*	0.54*	0.52*
LEFT GRIP					0.58*	0.61*	0.55*	0.67*	0.49*	0.46*	0.39**	0.61*
ELBOW FLEXION RIGHT						0.71*	0.46*	0.45*	0.50*	0.56*	0.62*	0.62*
ELBOW FLEXION LEFT							0.35**	0.53*	0.47*	0.35**	0.40**	0.42*
ELBOW EXTENSION RIGHT								0.63*	0.65*	0.74*	0.45*	0.58*
ELBOW EXTENSION LEFT									0.50*	0.46*	0.39**	0.59*
KNEE EXTENSION RIGHT										0.84*	0.62*	0.53*
KNEE EXTENSION LEFT											0.60*	0.51*
LEG LIFT												0.55*

* Critical t of 2.72 at the 0.01 level of confidence
** Critical to of 2.03 at the 0.05 level of confidence

TABLE LXVII

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE EIGHT FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	* 0.41	** 0.31	* 0.40	* 0.45	0.16	0.14	* 0.48	0.20	0.12	0.07	0.08	** 0.37
HEIGHT		* 0.56	0.19	** 0.33	0.14	0.09	** 0.34	* 0.42	0.06	0.14	-0.03	** 0.35
WEIGHT			0.20	** 0.36	** 0.30	0.05	0.24	0.27	0.24	0.13	0.07	0.24
RIGHT GRIP				* 0.76	** 0.31	** 0.31	* 0.56	** 0.34	0.16	0.24	-0.08	** 0.29
LEFT GRIP					0.20	0.22	* 0.52	** 0.34	0.12	0.23	-0.03	** 0.35
ELBOW FLEXION RIGHT						* 0.78	* 0.57	* 0.58	* 0.43	** 0.34	** 0.29	* 0.38
ELBOW FLEXION LEFT							* 0.54	* 0.54	* 0.40	* 0.43	* 0.44	* 0.46
ELBOW EXTENSION RIGHT								* 0.75	** 0.36	** 0.37	0.15	* 0.51
ELBOW EXTENSION LEFT									** 0.30	* 0.39	0.17	* 0.51
KNEE EXTENSION RIGHT										* 0.76	* 0.57	* 0.48
KNEE EXTENSION LEFT											* 0.63	* 0.52
LEG LIFT												* 0.41

* Critical t of 2.70 at the 0.01 level of confidence
** Critical t of 2.0 at the 0.05 level of confidence

TABLE LXVIII

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE NINE FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.26	0.21	0.28	0.19	0.22	0.20	0.22	0.15	0.34**	0.25	0.14	0.12
HEIGHT		0.46*	0.23	0.36**	0.29**	0.39*	0.29**	0.29**	0.32**	0.24	0.43*	0.31**
WEIGHT			0.55*	0.54*	0.63*	0.71*	0.75*	0.65*	0.56*	0.51*	0.57*	0.52*
RIGHT GRIP				0.85*	0.60*	0.63*	0.68*	0.67*	0.52*	0.44*	0.65*	0.59*
LEFT GRIP					0.56*	0.63*	0.65*	0.67*	0.44*	0.38*	0.51*	0.55*
ELBOW FLEXION RIGHT						0.90*	0.81*	0.79*	0.55*	0.53*	0.67*	0.62*
ELBOW FLEXION LEFT							0.83*	0.79*	0.57*	0.58*	0.69*	0.53*
ELBOW EXTENSION RIGHT								0.85*	0.66*	0.58*	0.64*	0.59*
ELBOW EXTENSION LEFT									0.61*	0.54*	0.62*	0.48*
KNEE EXTENSION RIGHT										0.89*	0.68*	0.39*
KNEE EXTENSION LEFT											0.64*	0.26
LEG LIFT												0.56*

* Critical t of 2.69 at the 0.01 level of confidence
** Critical t of 2.01 at the 0.05 level of confidence

TABLE LXIX

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE TEN FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.26	0.22	-0.07	-0.04	0.20	0.18	-0.08	0.07	0.11	-0.24	-0.13	0.02
HEIGHT		0.87*	0.36**	0.27	0.58*	0.50*	0.48*	0.43*	0.12	0.01	0.13	0.45*
WEIGHT			0.52*	0.48*	0.62*	0.53*	0.60*	0.58*	0.24	0.12	0.17	0.58*
RIGHT GRIP				0.85*	0.54*	0.57*	0.39*	0.42*	0.25	0.41*	0.20	0.44*
LEFT GRIP					0.40*	0.45*	0.33**	0.35**	0.15	0.28**	0.15	0.37*
ELBOW FLEXION RIGHT						0.66*	0.60*	0.63*	0.45*	0.44*	0.46*	0.42*
ELBOW FLEXION LEFT							0.56*	0.58*	0.32**	0.34**	0.14	0.40*
ELBOW EXTENSION RIGHT								0.81*	0.31**	0.24	0.28**	0.58*
ELBOW EXTENSION LEFT									0.35**	0.33**	0.36**	0.54*
KNEE EXTENSION RIGHT										0.83*	0.57*	0.34**
KNEE EXTENSION LEFT											0.51*	0.30**
LEG LIFT												0.23

* Critical t of 2.69 at the 0.01 level of confidence
** Critical t of 2.01 at the 0.05 level of confidence

TABLE LXX

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE ELEVEN FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.42*	0.31**	0.16	0.23	0.06	0.11	0.28	0.16	0.08	-0.06	-0.12	0.17
HEIGHT		0.80*	0.51*	0.48*	0.41*	0.42*	0.63*	0.51*	0.54*	0.33**	0.29**	0.67*
WEIGHT			0.64*	0.64*	0.57*	0.54*	0.69*	0.55*	0.46*	0.26	0.31**	0.74*
RIGHT GRIP				0.86*	0.57*	0.42*	0.67*	0.54*	0.46*	0.34**	0.38*	0.73*
LEFT GRIP					0.61*	0.49*	0.60*	0.57*	0.45*	0.29**	0.31**	0.73*
ELBOW FLEXION RIGHT						0.79*	0.67*	0.63*	0.65*	0.58*	0.62*	0.63*
ELBOW FLEXION LEFT							0.63*	0.71*	0.58*	0.52*	0.53*	0.61*
ELBOW EXTENSION RIGHT								0.76*	0.44*	0.40*	0.27	0.70*
ELBOW EXTENSION LEFT									0.45*	0.46*	0.33**	0.67*
KNEE EXTENSION RIGHT										0.81*	0.45*	0.48*
KNEE EXTENSION LEFT											0.43*	0.35**
LEG LIFT												0.48*

* Critical t of 2.70 at the 0.01 level of confidence
** Critical t of 2.01 at the 0.05 level of confidence

TABLE LXXI

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE TWELVE FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.05	0.04	0.14	0.23	-0.01	-0.06	-0.02	0.01	0.02	0.12	0.04	0.06
HEIGHT		* 0.77	* 0.59	* 0.49	* 0.41	* 0.45	0.27	** 0.31	** 0.35	** 0.37	0.24	* 0.61
WEIGHT			* 0.66	* 0.66	* 0.48	* 0.54	** 0.34	* 0.47	* 0.40	* 0.41	** 0.30	* 0.64
RIGHT GRIP				* 0.86	* 0.61	* 0.65	* 0.46	* 0.61	* 0.54	* 0.61	* 0.46	* 0.66
LEFT GRIP					* 0.49	* 0.58	* 0.49	* 0.59	* 0.59	* 0.68	* 0.55	* 0.59
ELBOW FLEXION RIGHT						* 0.81	* 0.68	* 0.72	* 0.56	* 0.54	* 0.54	* 0.54
ELBOW FLEXION LEFT							* 0.70	* 0.80	* 0.68	* 0.69	* 0.57	* 0.56
ELBOW EXTENSION RIGHT								* 0.65	* 0.62	* 0.59	* 0.47	* 0.43
ELBOW EXTENSION LEFT									* 0.70	* 0.74	* 0.55	* 0.55
KNEE EXTENSION RIGHT										* 0.91	* 0.67	* 0.65
KNEE EXTENSION LEFT											* 0.71	* 0.71
LEG LIFT												* 0.41

* Critical t of 2.70 at the 0.01 level of confidence
** Critical t of 2.02 at the 0.05 level of confidence

TABLE LXXII

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE THIRTEEN FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.26	0.22	0.18	0.12	0.29	0.19	0.21	0.12	0.17	0.20	0.12	0.34**
HEIGHT		0.53*	0.56*	0.39**	0.39**	0.27	0.24	0.03	0.22	0.19	-0.02	0.39**
WEIGHT			0.56*	0.54*	0.49*	0.56*	0.45*	0.28	0.48*	0.56*	-0.01	0.33
RIGHT GRIP				0.65*	0.51*	0.48*	0.34**	0.20	0.38**	0.29	0.01	0.62*
LEFT GRIP					0.35**	0.41**	0.15	0.01	0.14	0.19	-0.12	0.53*
ELBOW FLEXION RIGHT						0.72*	0.65*	0.54*	0.51*	0.62*	0.34**	0.60*
ELBOW FLEXION LEFT							0.57*	0.59*	0.43**	0.49*	0.26	0.52*
ELBOW EXTENSION RIGHT								0.84*	0.39**	0.48*	0.20	0.20
ELBOW EXTENSION LEFT									0.29	0.37**	0.08	0.11
KNEE EXTENSION RIGHT										0.85*	0.39**	0.48*
KNEE EXTENSION LEFT											0.46*	0.53*
LEG LIFT												0.35**

* Critical t of 2.75 at the 0.01 level of confidence
** Critical t of 2.04 at the 0.05 level of confidence

TABLE LXXIII

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE FOURTEEN FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	-0.30	-0.10	-0.08	0.14	-0.31	-0.13	-0.38**	-0.25	-0.21	-0.18	-0.13	-0.09
HEIGHT		0.58*	0.36**	0.22	0.35**	0.26	0.40**	0.39**	0.39**	0.25	0.44*	0.28
WEIGHT			0.49*	0.42**	0.28	0.33	0.41**	0.31	0.32	0.23	0.35**	0.37**
RIGHT GRIP				0.66*	0.26	0.12	0.42**	0.35**	0.43**	0.34**	0.59*	0.67*
LEFT GRIP					0.32	0.27	0.39**	0.35**	0.40**	0.45*	0.49*	0.48*
ELBOW FLEXION RIGHT						0.76*	0.62*	0.63*	0.59*	0.58*	0.58*	0.48*
ELBOW FLEXION LEFT							0.56*	0.64*	0.52*	0.48*	0.53*	0.35**
ELBOW EXTENSION RIGHT								0.89*	0.58*	0.66*	0.60*	0.55*
ELBOW EXTENSION LEFT									0.68*	0.75*	0.68*	0.49*
KNEE EXTENSION RIGHT										0.79*	0.71*	0.50*
KNEE EXTENSION LEFT											0.69*	0.43*
LEG LIFT												0.61*

* Critical t of 2.75 at the 0.01 level of confidence
** Critical t of 2.04 at the 0.05 level of confidence

TABLE LXXIV

ZERO ORDER CORRELATIONS FOR ALL PARAMETERS OF AGE FIFTEEN FEMALES

	HEIGHT	WEIGHT	RIGHT GRIP	LEFT GRIP	ELBOW FLEXION RIGHT	ELBOW FLEXION LEFT	ELBOW EXTENSION RIGHT	ELBOW EXTENSION LEFT	KNEE EXTENSION RIGHT	KNEE EXTENSION LEFT	LEG LIFT	BACK LIFT
AGE	0.06	0.06	0.07	0.06	** 0.42	0.31	* 0.46	** 0.40	0.27	0.29	-0.12	0.23
HEIGHT		0.19	0.27	0.16	0.10	0.00	0.13	0.17	0.16	0.22	0.26	0.32
WEIGHT			0.32	** 0.42	** 0.36	** 0.36	0.32	** 0.38	-0.14	-0.04	-0.06	-0.05
RIGHT GRIP				* 0.84	* 0.50	* 0.57	* 0.35	0.18	0.32	* 0.38	0.22	* 0.47
LEFT GRIP					** 0.41	* 0.50	0.27	0.22	0.18	0.24	0.18	0.31
ELBOW FLEXION RIGHT						* 0.69	* 0.76	** 0.44	** 0.44	* 0.48	0.26	0.31
ELBOW FLEXION LEFT							* 0.63	* 0.47	** 0.41	** 0.44	** 0.35	** 0.41
ELBOW EXTENSION RIGHT								** 0.44	* 0.53	* 0.50	0.30	** 0.36
ELBOW EXTENSION LEFT									** 0.35	0.31	0.20	** 0.36
KNEE EXTENSION RIGHT										* 0.93	* 0.67	* 0.69
KNEE EXTENSION LEFT											* 0.62	* 0.59
LEG LIFT												* 0.54

* Critical t of 2.76 at the 0.01 level of confidence
** Critical t of 2.04 at the 0.05 level of confidence

TABLE LXXV

PERCENTILE NORMS FOR MALE HEIGHT IN INCHES

	P10	P25	P50	P75	P90
Age 7	47	49	50	51	52
Age 8	48	50	51	53	54
Age 9	51	52	54	56	57
Age 10	52	54	56	57	59
Age 11	55	56	58	59	61
Age 12	57	59	62	63	65
Age 13	59	61	62	65	68
Age 14	62	64	66	69	71
Age 15	64	65	68	69	71

TABLE LXXVI

PERCENTILE NORMS FOR MALE WEIGHT IN POUNDS

	P10	P25	P50	P75	P90
Age 7	48	51	55	60	71
Age 8	51	55	61	65	75
Age 9	57	61	66	75	86
Age 10	59	68	74	85	97
Age 11	65	72	81	99	115
Age 12	77	86	100	107	128
Age 13	85	91	103	116	130
Age 14	107	117	134	148	180
Age 15	103	122	134	147	165

TABLE LXXVII

PERCENTILE NORMS FOR MALE STRENGTH OF RIGHT GRIP

	P10	P25	P50	P75	P90
Age 7	21	25	29	31	36
Age 8	24	29	33	36	41
Age 9	29	34	37	41	46
Age 10	29	36	42	46	56
Age 11	31	36	43	50	55
Age 12	39	47	51	58	64
Age 13	44	50	54	59	69
Age 14	59	67	73	86	94
Age 15	64	67	81	96	110

TABLE LXXVIII
PERCENTILE NORMS FOR MALE STRENGTH OF LEFT GRIP

	P10	P25	P50	P75	P90
Age 7	18	23	28	30	34
Age 8	24	28	31	35	39
Age 9	28	32	36	40	45
Age 10	29	36	40	45	51
Age 11	30	34	41	47	54
Age 12	39	43	48	53	67
Age 13	43	48	53	59	65
Age 14	55	68	74	79	88
Age 15	63	73	83	92	103

TABLE LXXIX
PERCENTILE NORMS FOR MALE RIGHT ELBOW FLEXION STRENGTH

	P10	P25	P50	P75	P90
Age 7	18	21	23	27	31
Age 8	21	25	29	32	28
Age 9	26	29	33	39	41
Age 10	29	33	35	38	47
Age 11	28	34	39	45	52
Age 12	34	39	46	58	65
Age 13	38	46	54	69	76
Age 14	41	56	67	80	96
Age 15	49	63	78	93	106

TABLE LXXX
PERCENTILE NORMS FOR MALE LEFT ELBOW FLEXION STRENGTH

	P10	P25	P50	P75	P90
Age 7	18	21	24	29	33
Age 8	21	25	28	30	34
Age 9	24	30	32	39	43
Age 10	26	31	34	41	47
Age 11	27	32	39	44	52
Age 12	33	38	46	54	65
Age 13	39	47	53	62	78
Age 14	43	54	63	76	97
Age 15	48	58	75	86	102

TABLE LXXXI
PERCENTILE NORMS FOR MALE RIGHT ELBOW EXTENSION STRENGTH

	P10	P25	P50	P75	P90
Age 7	14	18	21	25	28
Age 8	18	22	25	28	32
Age 9	17	27	29	33	34
Age 10	25	27	32	34	41
Age 11	26	28	33	39	43
Age 12	31	32	36	44	51
Age 13	32	35	43	51	62
Age 14	43	46	54	66	73
Age 15	41	54	65	78	86

TABLE LXXXII
PERCENTILE NORMS FOR MALE LEFT ELBOW EXTENSION STRENGTH

	P10	P25	P50	P75	P90
Age 7	15	18	21	25	30
Age 8	18	21	25	29	31
Age 9	21	23	27	30	33
Age 10	23	25	31	33	38
Age 11	25	29	34	39	43
Age 12	29	32	38	47	49
Age 13	32	34	44	53	63
Age 14	34	46	54	67	82
Age 15	42	48	63	82	86

TABLE LXXXIII
PERCENTILE NORMS FOR MALE RIGHT KNEE EXTENSION STRENGTH

	P10	P25	P50	P75	P90
Age 7	29	35	44	51	63
Age 8	36	45	53	62	71
Age 9	50	53	66	74	83
Age 10	52	60	67	79	88
Age 11	55	65	78	92	106
Age 12	59	70	78	100	111
Age 13	54	74	86	111	114
Age 14	81	98	111	128	144
Age 15	73	97	115	147	167

TABLE LXXXIV
PERCENTILE NORMS FOR MALE LEFT KNEE EXTENSION STRENGTH

	P10	P25	P50	P75	P90
Age 7	28	33	43	50	54
Age 8	34	43	50	59	67
Age 9	42	50	65	73	84
Age 10	48	56	66	73	89
Age 11	53	62	78	88	108
Age 12	58	66	84	99	112
Age 13	62	70	86	103	114
Age 14	79	89	102	123	142
Age 15	90	98	115	138	155

TABLE LXXXV
PERCENTILE NORMS FOR MALE LEG LIFT STRENGTH

	P10	P25	P50	P75	P90
Age 7	75	89	103	142	180
Age 8	95	113	145	180	203
Age 9	138	155	190	233	270
Age 10	148	168	208	245	310
Age 11	160	183	237	285	350
Age 12	185	208	273	340	435
Age 13	228	258	300	387	453
Age 14	245	293	363	413	490
Age 15	245	335	413	553	608

TABLE LXXXVI
PERCENTILE NORMS FOR MALE BACK LIFT STRENGTH

	P10	P25	P50	P75	P90
Age 7	54	58	73	83	90
Age 8	58	65	83	93	100
Age 9	73	85	105	120	138
Age 10	85	89	105	125	135
Age 11	92	108	125	140	150
Age 12	103	128	143	160	187
Age 13	118	135	155	183	188
Age 14	150	173	195	223	243
Age 15	158	188	205	245	273

TABLE LXXXVII
PERCENTILE NORMS FOR FEMALE HEIGHT IN INCHES

	P10	P25	P50	P75	P90
Age 7	46	48	50	51	52
Age 8	48	49	51	52	53
Age 9	51	52	53	56	58
Age 10	52	53	55	57	58
Age 11	55	56	59	61	63
Age 12	56	59	61	63	65
Age 13	59	60	62	64	65
Age 14	60	61	64	65	67
Age 15	60	62	63	65	67

TABLE LXXXVIII
PERCENTILE NORMS FOR FEMALE WEIGHT IN POUNDS

	P10	P25	P50	P75	P90
Age 7	47	50	55	61	67
Age 8	47	50	56	62	68
Age 9	55	61	65	79	85
Age 10	55	64	73	80	88
Age 11	69	72	88	100	121
Age 12	76	86	97	107	119
Age 13	87	92	109	120	135
Age 14	98	104	116	124	129
Age 15	93	112	116	127	150

TABLE LXXXIX
PERCENTILE NORMS FOR FEMALE GRIP STRENGTH RIGHT

	P10	P25	P50	P75	P90
Age 7	20	23	27	30	32
Age 8	21	24	30	33	35
Age 9	26	29	31	35	42
Age 10	30	32	35	41	43
Age 11	34	37	42	46	57
Age 12	37	41	47	54	59
Age 13	42	47	52	61	67
Age 14	47	53	56	61	69
Age 15	45	53	63	67	73

TABLE XC
PERCENTILE NORMS FOR FEMALE LEFT GRIP STRENGTH

	P10	P25	P50	P75	P90
Age 7	20	21	25	28	32
Age 8	21	23	28	31	32
Age 9	24	28	30	33	39
Age 10	25	30	34	37	41
Age 11	33	36	41	45	51
Age 12	32	37	43	54	57
Age 13	41	46	54	57	61
Age 14	44	47	55	59	70
Age 15	53	54	58	63	69

TABLE XCI
PERCENTILE NORMS FOR FEMALE RIGHT ELBOW LEXION STRENGTH

	P10	P25	P50	P75	P90
Age 7	20	21	24	27	32
Age 8	18	23	26	29	31
Age 9	22	25	28	32	37
Age 10	26	30	33	38	41
Age 11	28	34	40	45	52
Age 12	32	36	43	48	52
Age 13	34	40	48	52	66
Age 14	27	33	38	45	56
Age 15	39	43	49	53	62

TABLE XCII
PERCENTILE NORMS FOR FEMALE LEFT ELBOW FLEXION STRENGTH

	P10	P25	P50	P75	P90
Age 7	17	21	24	27	32
Age 8	18	22	25	29	33
Age 9	22	26	30	34	43
Age 10	26	30	35	38	42
Age 11	28	32	37	46	51
Age 12	28	34	43	49	54
Age 13	34	38	48	52	61
Age 14	31	33	40	47	48
Age 15	34	41	47	51	63

TABLE XCIII
PERCENTILE NORMS FOR FEMALE RIGHT ELBOW EXTENSION STRENGTH

	P10	P25	P50	P75	P90
Age 7	15	18	20	23	24
Age 8	16	21	22	24	26
Age 9	18	21	24	28	33
Age 10	21	25	28	31	33
Age 11	23	28	33	39	41
Age 12	26	30	33	42	48
Age 13	26	31	43	49	52
Age 14	25	30	36	42	48
Age 15	26	34	40	44	49

TABLE XCIV
PERCENTILE NORMS FOR FEMALE LEFT ELBOW EXTENSION STRENGTH

	P10	P25	P50	P75	P90
Age 7	14	16	21	24	26
Age 8	16	18	22	24	26
Age 9	19	21	23	29	32
Age 10	22	23	28	30	33
Age 11	25	26	31	36	39
Age 12	27	29	34	40	51
Age 13	27	33	41	49	54
Age 14	24	28	36	40	46
Age 15	33	34	39	46	48

TABLE XCV
PERCENTILE NORMS FOR FEMALE RIGHT KNEE EXTENSION STRENGTH

	P10	P25	P50	P75	P90
Age 7	33	39	47	53	60
Age 8	37	43	49	61	65
Age 9	40	52	58	72	81
Age 10	49	55	69	78	86
Age 11	52	62	78	85	97
Age 12	61	67	81	94	118
Age 13	62	82	93	106	123
Age 14	52	66	86	97	111
Age 15	51	63	89	106	111

TABLE XCVI
PERCENTILE NORMS FOR FEMALE LEFT KNEE EXTENSION STRENGTH

	P10	P25	P50	P75	P90
Age 7	33	39	42	58	63
Age 8	33	39	49	54	67
Age 9	36	53	62	76	88
Age 10	47	54	69	81	92
Age 11	47	58	73	88	101
Age 12	50	67	79	93	111
Age 13	59	81	88	103	123
Age 14	46	67	81	93	102
Age 15	45	69	86	103	113

TABLE XCVII
PERCENTILE NORMS FOR FEMALE LEG LIFT STRENGTH

	P10	P25	P50	P75	P90
Age 7	66	83	95	140	183
Age 8	85	105	130	153	175
Age 9	93	142	195	220	250
Age 10	138	160	198	237	283
Age 11	140	180	217	280	363
Age 12	145	190	245	333	380
Age 13	167	200	240	313	410
Age 14	125	153	228	283	350
Age 15	143	183	258	300	400

TABLE XCVIII
PERCENTILE NORMS FOR FEMALE BACK LIFT STRENGTH

	P10	P25	P50	P75	P90
Age 7	44	48	65	80	89
Age 8	51	63	73	82	89
Age 9	60	73	83	100	110
Age 10	73	83	93	103	118
Age 11	83	92	113	133	148
Age 12	92	105	133	143	168
Age 13	113	120	145	155	185
Age 14	100	115	138	160	168
Age 15	105	128	145	158	173

Discussion

It was the purpose of the present study to provide an investigation into chronological age and sex variability in basic muscular strength occurring in a random sample of seven to fifteen year old boys and girls, as well as to provide percentile norms for the various strength measures taken. Hunsicker and Greey (37:119) have observed that four fifths of an adult's strength but hardly more than one third of his height is acquired after age six. The present study lends support to this observation. The following discussion relates the present findings to studies of a similar purpose already carried out.

The British investigator Galton (33) found that male arm strength of different age samples increased rapidly from age twelve to nineteen. The results for the present for four arm strength parameters were very similar with larger increases found beginning at twelve year samples. For female samples he found "uniform" increased starting at nine years, with a loss of uniformity after thirteen years of age.

The 1930 American Committee on Growth and Development (21) found that there was no characteristic rate or style of muscular growth for various muscular groups from birth to maturity. The present study, which is limited to ages seven to fifteen, found strength to triple for nine of the ten male strength measures. The only change not being uniform to the "triple" observation was for leg lift which quadrupled. Without exception the female samples tested doubled their strength on all ten of the strength tests administered between ages seven and fifteen years. The American Committee Study (21) was based on muscular bulk increases rather than actual strength increases.

Shuttleworth (61) reported on maximum periods of height growth for male and female samples. Female samples studied exhibited a sharp spurt between 10.5 and twelve years. A similar sharp spurt for female height gain was found in the present study. For males a sharp increase occurred between thirteen and fourteen in Shuttleworth's data, while for the present study two sharp increases of similar magnitude (3.5 inches) were found for ages eleven to twelve, and thirteen to fourteen.

Jones (43) reported on the California Adolescent Growth Study in 1949, in which a group of 183 boys and girls were studied longitudionally twice per year for seven years. The strength measures included grip strength and push and pull strength. The study by Jones used a elliptical type "Collins" spring dynamometer (for strength of grip), while the present study used a Smedley Adjustable Grip Dynamometer. The present study was based on cross-sectional data. The testing in the Jones' study was made competitive, while in the present study it was not.

Trial to trial reliability coefficients for the results of the California study (43:9) ranged from .932 to .964 with little difference between the various ages. Somewhat lower reliability coefficients were reported for 72 boys remeasured after an interval of one week. In the present study the reliability coefficients, based on trial one versus trial two, ranged from 0.73 to 0.97 for male right grip strength. For female right grip strength of the present study the reliability coefficients ranged from 0.78 to 0.94 (two coefficients were below 0.78). Male left grip coefficients ranged from 0.78 to 0.95, while for female left grip coefficients the range was 0.77 to 0.96. Elbow flexion coefficients of reliability in the present study ranged from 0.70 to 0.94

for females, and 0.86 to 0.94 for males. In the present study reliability coefficients, based on a complete retest, with a one to four week interval, were found to range from 0.81 (leg lift) to 0.96 (elbow flexion). The two grip strength coefficients were 0.91 and 0.95 for right and left grip respectively.

Jones (43:20) reported on several correlations between measures. For 72 boys right grip strength intercorrelated with back lift 0.59 in the California study. In the present study this intercorrelation was 0.72 for 73 boys aged twelve to thirteen. In the California study right grip intercorrelated 0.66 with leg lift, whereas in the present study this correlation was 0.48. The present study found back lift and leg lift to intercorrelate 0.47, while for the Jones' study this intercorrelation was 0.67. In the California study the correlation between strength and either height or weight was not found to be high. The present study was of the same order but did find some medium range correlations at age fifteen between weight and strength. For example, as Table LXV indicates, the correlation between weight and elbow extension strength (left) was 0.73, and between weight and elbow flexion strength (right) was 0.71.

The California study contained data for the growth of strength. For males mean grip strength was 25 kilograms, while for females male mean grip strength was 21 kilograms, both at eleven years of age. The present study found male mean grip strength to be 19.6 kilograms, while female grip strength was 19.6 kilograms, also at age eleven. Jones discovered that by age thirteen male and female mean grip strength had remained nearly four kilograms apart, while the present study found that at age

thirteen male and female grip strengths were less than one kilogram apart. The present study found similarities with the California grip strength growth curves in that female growth slowed slightly at thirteen years but at 14.5 years it gained rapidly again. For male grip strength the present study showed a rapid increase after thirteen years of age. Jones showed (43:35) that the basic pattern of growth outlined for right grip strength was duplicated nearly exactly for left grip strength. The present study found similar results. Both studies found the magnitude of scores to be less for left hand grip strength. Regarding standard deviation size, Jones found a relatively regular increase as age progressed. In the present study standard deviation size was found to increase with age for the grip strength tests. The largest relative gain in mean strength of right grip for boys was 9.7 percent between 14.5 and fifteen years in the California study. Based on a one year interval the present study found the largest relative gain to be 34.9 percent between thirteen and fourteen years of age. The largest relative gain in mean right grip strength for girls was 9.2 percent between 12.0 and 12.5 years in the California study. Based on a one year interval the present study found the largest relative gain to be 21.1 percent between ten and eleven years of age. Thus, while the present study found a similar relative gain for females, the male relative gain was not the same.

The pattern of growth in the California study was characterized in some of the following ways. In each strength parameter girls showed a period of secondary increase falling about three years after the principal peak of growth. Jones also found a characteristic slowing of strength increments between 12.5 and thirteen years of age, followed by a spurt

between male and female grip strength were less than that for thirteen years. The present study found statistically that the California grip strength growth curve of that female growth slowed slightly at thirteen years, but at 14.5 years it seemed rapidly again. For male grip strength the present study showed a small increase after thirteen years of age. Jones showed (1949) that the annual pattern of growth following the right grip strength was equivalent closely the left grip strength. The present study found similar results. Both studies found the magnitude of scores to be less for left hand grip strength, suggesting dominant hand grip also. Jones found a relatively regular increase in age increments. In the present study somewhat variation also was found in increments with the in- the grip strength means. The largest relative gain in mean strength of right grip for boys was 9.7 percent between 11.5 and fifteen years in the California group. Based on a one year interval the present study found the largest relative gain to be 15.7 percent between thirteen and fourteen years of age. The largest relative gain in mean right grip strength for girls was 8.2 percent between 11.5 and 12.5 years in the California study. Based on a one year interval the present study found the largest relative gain to be 21.4 percent between ten and eleven years of age. Thus, while the present study showed a similar relative gain for females the male relative gain was not the same.

The pattern of growth in the California study was characterized by some of the following steps. In each strength parameter girls showed a period of accelerating increases falling about three years after the individual peak of growth. Jones also found a characteristic interval increments between 14.5 and fourteen years of age, followed by a ...

to a period of maximal increments in male samples. In the present study there was found a period of secondary increase in female grip strength curves. This characteristic was only found for grip strength. The secondary increase occurred two years after the primary increase (see Figure III). The present study found a characteristic slowing of strength increase previous to a spurt to maximal increments in males. The characteristic slowing was between twelve and thirteen years for the grip strength and the knee extension tests. For the elbow flexion and elbow extension tests this slowing occurred earlier or between the age ten and eleven levels. Leg lift strength and back lift strength did not show this characteristic.

Jones (43:64) noted some controversy in regard to the possible diminished motivation of girls in adolescence to perform measures of maximal physical strength. Jones feels that it is probably true that in later adolescence girls are, in general, less readily motivated than boys in physical activity tests. The present study found that in many of the strength measures girls of age fourteen exhibited less strength than girls at age thirteen. By age fifteen the mean strength was similar to that of a thirteen year sample. In the eight strength tests in which an age thirteen sample was superior to an age fourteen sample, significant differences in favor of the thirteens was found for four of the eight tests at the 0.01 level of confidence. Two possible explanations for this finding are immediately evident. The first explanation would suggest a decreased level of motivation. Secondly, it may possibly be that the fourteen year old sample was a weaker sample. However, one finding would indicate that neither of these possible explanations is correct. It was

found in the grip strength tests that fourteen year old girls were not weaker than the thirteen year sample. The mean difference in favor of the fourteen year sample was not enough to reach significance at the 0.01 level of confidence. The method of selecting the fourteen year sample was as stringent as for all other samples selected. Any explanation of decreased strength in a fourteen year old sample based on lowered motivation at adolescence would have to explain the increase of the fifteen year samples. The present study can offer no further explanation for the findings.

Jones (43:99) compared his findings for grip strength with other normative data. In general he found that appearance of other grip strength growth curves was similar, but there were large differences in absolute level. There was a similar divergence of boys and girls in grip strength after thirteen years of age. For boys the poorest performance was for the London sample. A New York public school group was not superior to the London group until after sixteen years. The present sample of Edmonton male school children was superior in absolute terms to the London sample, the New York public school sample, and a Chicago sample. It was also found to be superior to a New York private school sample after 13.5 years of age. The Edmonton male sample was less than an Iowa sample except at age fourteen, when the present sample was slightly superior. The Oakland sample was superior at all ages. Interpretations of these comparisons is made cautiously due to test administration differences, scoring differences, motivation differences, instrumentation differences, and timing differences. The appearance of the Edmonton growth curve was similar to the Oakland curve initially, but the gain between age thirteen and fourteen samples

was greater for the Edmonton sample. The Edmonton girls' samples were stronger than samples from London, Michigan and Chicago. Similarities at ages eleven, twelve, and thirteen were found between the Iowa, and the New York private school samples when compared to the Edmonton sample. The Iowa and New York private school samples gained noticeably on the Edmonton sample after age thirteen. The Oakland sample was superior to the Edmonton sample at all ages. More similarities existed in the grip strength growth curves between the Edmonton and Oakland samples than for any other two compared samples.

The dextrality coefficients reported by Jones (43:103) resulted in male right grip - left grip correlations of .834, .780, and .868 for ages 11.5 - 11.9, 13.5 - 13.9, and 15.0 - 15.9 respectively. Corrected for attenuation these coefficients do not exceed 0.90 at maximum. Not more than about 80 percent of the variance can be accounted for in terms of the scores for the other hand. The present study found correlations at the same ages of 0.86, 0.84, and 0.81 respectively. Thus the present study accounted for nearly the same amount of variance. The present study found reliabilities only slightly less than the Oakland ones. The female right grip - left grip correlations were less in both the Oakland and the Edmonton samples.

Bookwalter (7) reported grip strength norms in 1950 for several states. He found slight progression between nine and fourteen years, and accelerated progression between fourteen and seventeen. Nine year olds had the smallest grip strength, 42 pounds. The present study resulted in a left hand grip strength curve that was similar in pattern but lower in absolute terms by nearly ten pounds at ages nine, ten, and eleven. The

twelve year sample gained strongly in the present study, and was identical to the twelve year mean left grip strength of Bookwalter's study. A slight gain between age twelve and thirteen was found in both studies. At age thirteen the present study found that grip strength increased rapidly. A parallel increase of lesser magnitude was found in the Bookwalter study. The fourteen and fifteen year Edmonton sample was ahead of the Bookwalter sample by nearly ten pounds. For right hand grip strength the Edmonton sample surpassed the Bookwalter sample somewhat earlier than had been the case for left grip strength. In the Bookwalter study (7) right hand grip strength was consistently greater than left hand mean grip strength. The present study found this to be true up to the fifteen year sample, in which the left hand surpassed the right by a small amount (difference = 0.09 pounds). The true handedness for the present study is shown in the appendix.

Torpey (69) reported that right knee extension strength was found to be 53 pounds for grade one boys, and 95 pounds at grade six. For girls the mean scores were 52 pounds and 95 pounds respectively. In the present study the knee extension strength was 44 pounds at age seven and 84 pounds at age twelve, while for girls these means were 47 pounds and 83 pounds respectively.

A gain of some 149 percent in mean right grip strength for age nine to fifteen males was reported by Clake and Wickens (19:33) for a Medford, Oregon sample. They reported nine year mean grip strength to be 17.7 kilograms, and fifteen year strength to be 44.1 kilograms. For left grip the gain was from 16.7 kilograms to 41.7 kilograms for the same ages. This gain equals 150 percent. The present study found age nine right

grip strength to be 17.14 kilograms, and age fifteen strength to be 37.55 kilograms, a gain of 119 percent. For left grip the two parallel mean scores were 16.48 kilograms and 37.60 kilograms. The gain in percent was 128. Clarke and Wickens also reported age nine and fifteen back lift and leg lift scores. They found back lift scores of 69 kilograms, and 148 kilograms at nine and fifteen years respectively. The gain was 115 percent. For leg lift the gain was 175 percent beginning at 175 kilograms and reaching 482 kilograms at fifteen years. The present study found lower scores for both of these parameters, for back lift the age nine mean was 47.11 kilograms and the age twelve mean was 97.72 kilograms, while for leg lift the age nine mean was 88.38 kilograms and the age fifteen was 219.09 kilograms. The increase for back lift in the present study was 107 percent, while for leg lift it was 148 percent.

Fleishman (30) reported a number of percentile scores for strength measures on 20,000 boys and girls in some 45 American cities. Grip strength was tested by using a Narragansett hand dynamometer. The 50th percentiles for females were 42 pounds, 43 pounds, and 55 pounds respectively at age thirteen, fourteen, and fifteen. For the present study the 50th percentile scores were 52, 56 and 62 pounds respectively. For females Fleishman reported the 90th percentile scores to be 58,60 and 69 pounds for ages thirteen to fifteen. The 90th percentiles for the present study were 67, 69, and 73 pounds respectively. The 10th percentile scores were 24, 32, and 39 pounds respectively. For the same ages the present study found that the 10th percentiles were 42, 47, and 45 pounds respectively. The percentile norms for the Edmonton sample were greater in all cases than the large American sample norms for females.

For male samples the 50th percentiles for grip strength of the Fleishman sample were 65, 78 and 93 pounds respectively for ages thirteen, fourteen, and fifteen. In the present study the percentiles of the same ages were 54, 73, and 81 pounds respectively. The 90th percentile scores for males of the Fleishman sample were 85, 108 and 115 pounds respectively, while in the present study these norms were 69, 94, and 110 pounds. Finally, the 10th percentile for the American sample was 41, 46, and 69 pounds respectively. The present study found grip strength (right) for age thirteen, fourteen, and fifteen samples to be equal to percentile norm scores of 44, 59, and 64 pounds. It appears that a large sample of American boys meet higher percentile norm standards for all percentile levels above the 25th percentile than does a sample of Edmonton school boys. The precautions previously discussed apply to the comparison of percentile norms as well. The large sample of the Fleishman study provided sharper distinctions between the percentiles calculated.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

It was the basic purpose of the present investigation to discover the status of strength in Edmonton school children, aged seven to fifteen years. Age variability and sex variability of the ten strength measures were analyzed. Furthermore, age percentile norms for results of all of the strength tests were established. It was possible through the norms to establish basic standards, as well as to compare the strength status of Edmonton children with others. Correlations and reliabilities completed the analysis of the status of strength among the samples.

A sampling technique was used that consisted of listing each elementary, junior high school, and senior high school in the City of Edmonton, Alberta. Through the use of random number tables (25) a random sample of five schools from each level was selected, out of the total population of schools. Class lists were then used to list the total population of each age and sex level, of the randomly selected schools. Once again a table of random numbers was used to select out 1.25 percent of each age-sex population. A completely random sample was thus assured.

A strength testing machine was built which provided reproducible test postures, as well as bodily stability. By using belts, loops, chains, and cables, the machine aided in testing static isometric strength, by using the Cable Tensiometer Method (20). In addition, a Smedley Adjustable Grip Dynamometer was used for the test of grip strength.

Commencing in June of 1965 a two man test team visited the sample schools, and tested each selected subject. Age, height, and weight were recorded previous to the actual test. Each subject was then given ten tests that included: grip strength, arm strength, leg strength, leg lift strength, and back lift strength. Three trials for each test were given, and the subject was encouraged through the shout teachnique to do as well as possible. In general, the testing was carried out upon the younger samples first. Age was recorded as of the date on which the subject received the strength tests.

After the test completion, which took eight months in all, the results were analyzed through the use of appropriate statistics.

The reliabilities of the measures were found to be high, through trial to re-trial techniques, (range was 0.64 to 0.97) as well as test re-test techniques (range was 0.81 to 0.96).

For females the means for the youngest age groups were close to 25 pounds for the arm and grip measures. Girls' strength changed gradually with the year to year samples, until between ages ten and twelve, when it changed rapidly. After age twelve girls' strength increments either slowed, or in some cases resulted in negative changes. Girls' right side scores were usually lower than left side scores, and there was a tendency for right side strength to develop earlier (as found by test results), than left side strength. Girls were, in general, weaker in mean strength than were boys of the same age, even for lower ages. On occasion, when a sample of girls did demonstrate a mean score higher than boys of the same age, statistically significant differences did not occur. Girls of the Edmonton sample compared well, in absolute

terms with girl subjects in grip strength studies in other parts of the world. The measuring instruments, however, differed in these studies. While the Edmonton girls sample surpassed all or most scores from samples in London, Michigan, Chicago, New York (private school), and Iowa there appeared to be some suggestion, based on this study, that girls from the Edmonton sample tended to lose earlier advantages over two other samples. A sample from Oakland was superior to Edmonton girls at all ages. Percentile norms (grip strength) scores for Edmonton girls were higher in all cases than norms of a recently published National United States study involving 20,000 subjects (male and female), done by Fleishman (30).

For males the reliability coefficients were high by trial to re-trial, or test to re-test methods. Boys gained slowly and regularly in strength up to twelve years of age, when there appeared to be a level-off prior to large and significant increases in strength, between both thirteen and fourteen, and fourteen and fifteen years. A second period of prominent increases was between ten and twelve years of age. Boys' right side strength was not as dominant over left side strength as was the case with girls. Boys in the Edmonton sample did not compare to various other samples as well as did the Edmonton girls. While they were nearly the same comparatively as the girls were to other samples on grip strength, the boys' percentile norms (grip strength) were nearly all below the grip strength norms of the recent Fleishman United States study (30). Again these comparisons must be considered with caution.

Finally, it was evident that when a sex comparison was carried out, on the Edmonton sample, two age intervals were significantly different

in favor of the males. These differences tended to repeat themselves with the various strength tests carried out. It was found that males surpassed females (statistical significance beyond the 0.01 level of confidence) at ages eight, nine, and ten and again at fourteen and fifteen. The middle ages of the present sample differed little in strength between sexes.

Conclusions

1. The growth of height in girls is strongest between eight and twelve years of age, and it levels off until there is very little change between fourteen and fifteen years.

2. The growth of weight in girls continues on strongly for two years longer than for maximum height changes. The largest weight increment was found between ten and eleven years. There was only a small change between fourteen and fifteen years.

3. The growth of height in boys is strongest between eleven and twelve years and again between thirteen and fourteen years of age. Height was still changing beyond one inch per year between age samples of fourteen and fifteen years.

4. The growth of weight in boys is gradual but steady until between thirteen and fourteen years, when a large increase occurs. For the present samples this change is one-third of the age thirteen mean weight (105 pounds).

5. It is concluded that by using the tests of strength of the present study that highly reliable measures are obtainable.

6. For a sample of seven year old Edmonton boys the following mean scores resulted: grip strength is 28 pounds, arm strength (four measures)

is 23 pounds, leg strength is 43 pounds, leg lift strength is 116 pounds, and back lift strength is 73 pounds.

7. For a sample of fifteen year old Edmonton boys the following mean scores resulted: grip strength is 83 pounds, arm strength (four measures) is 70 pounds, leg strength is 120 pounds, leg lift strength is 427 pounds, and back lift strength is 215 pounds.

8. It is concluded that strength of boys is tripled, between samples aged seven to fifteen for grip strength, arm strength, leg strength, and back lift strength. Leg lift strength is quadrupled between ages seven and fifteen.

9. Regarding the ages when significant ($\alpha = 0.01$) mean strength changes occur in a sample of boys, it is concluded that fifteen year olds, fourteen year olds, and twelve year olds are significantly stronger over all younger age samples in most measures of the present study. Age nine male samples are significantly stronger in three of the measures over all younger ages.

10. It is concluded that male age samples other than fifteen, fourteen, and twelve year olds are in general significantly stronger ($\alpha = 0.01$) than age samples two years and more under the age sample specified. Nine year olds are an exception.

11. For a sample of seven year old Edmonton girls the following mean scores resulted: grip strength is 26 pounds, arm strength (four measures) is 22 pounds, leg strength is 47 pounds, leg lift strength is 111 pounds, and back lift strength is 67 pounds.

12. For a sample of fifteen year old Edmonton girls the following mean scores resulted: grip strength is 61 pounds, arm strength (four

measures) is 44 pounds, leg strength is 86 pounds, leg lift strength is 263 pounds, and back lift strength is 142 pounds.

13. It is concluded that strength of girls is doubled between samples aged seven and fifteen years for grip strength, arm strength, leg strength and back lift strength. Leg lift strength of fifteen year olds is 2 1/3 times that of seven year olds.

14. Regarding the ages when significant ($\alpha = 0.01$) mean strength changes occur in a sample of girls, it is concluded that eleven year olds are significantly stronger over all younger age samples in most measures of the present study. For half of the measures, age nine girls are significantly stronger over all other younger ages.

15. It is concluded that female age samples other than eleven and nine year olds are generally significantly stronger ($\alpha = 0.01$) than age samples two years or more under the age sample specified. For the test of leg lift strength among girls significant differences between age groups occurred even less readily.

16. For female samples it is concluded that fifteen year old and fourteen year old girls either gain very little in mean strength over younger ages, or in some cases actually have less mean strength, for the samples of the present study. For four strength measures the fourteen year sample tested was significantly below a thirteen year sample in mean strength.

17. It is concluded that female grip strength growth curves increase gradually to age ten, gain strongly between ten and eleven, level off between eleven and thirteen and gain strongly between thirteen and fifteen.

18. It is concluded that male grip strength growth curves increase slowly and gradually until age ten, level off between age ten and eleven, gain strongly and steadily until age thirteen when a sharp rapid increase occurs until age fourteen and slow slightly from this strong rate between ages fourteen and fifteen.

19. It is concluded that female mean strength growth curves for arm, leg, leg lift, and back lift strength show gradual mean increases in strength until ten years, show stronger increases between ten and eleven years, increase gradually between age eleven and thirteen, drop in mean strength between age thirteen and fourteen, while they gain back to the age thirteen level by age fifteen. It is also concluded that leg and back strength measures indicate that the strongest gain for these measures occurs one year later than did the strongest gain for arm measures.

20. It is concluded that male mean strength growth curves for arm, leg, and back left strength shows gradual increases until age ten, a level-off between age ten and eleven, increase strongly between eleven and twelve, level off again until thirteen, and increase greatly between thirteen and age fifteen. It is also concluded that leg lift strength follows a steady, nearly linear pattern of growth. The first level-off was earliest in leg extension strength.

21. It is concluded that samples of boys and girls differ significantly ($\alpha = 0.01$) for all measures of the study at ages fourteen and fifteen, in favor of boys.

22. It is concluded that samples of boys and girls differ significantly ($\alpha = 0.01$) for grip, arm, and back strength measures at

ages eight, and nine. This sex difference at age eight and nine is not found in leg extension or leg lift measures.

23. Measures of arm strength are concluded to be significantly different for right arm strength more often than they are for left arm strength measures, when sexes are compared.

24. It is concluded that at the middle ages of eleven and twelve years, and to a lesser extent at ages ten and thirteen, there are little or no sex differences occurring for strength measures, as taken in the present study.

25. Correlation coefficients for dextrality or right and left hand grip strength of the samples studied are concluded to be high, usually between 0.80 and 0.90 for zero order correlations.

26. Correlations between either height or weight and grip strength are mostly significantly different from zero but have not been found to be high correlations.

Recommendations:

1. Whereas physical education programs encourage muscular fitness it is recommended that curriculum planners, physical educators, and educationists generally, attempt to relate physical education program contents to the findings of the present study.

2. It is recommended that library copies of the present study be given to Edmonton School Boards, and that a summary of the study be made available to physical educators teaching at all grade levels. The summary should index important sections for reference to library copies.

3. Further investigation of the finding of relatively low fourteen

and fifteen year old female strength is recommended. Specifically, it is recommended that the original thirteen year, fourteen year, and fifteen year female samples be retested. Undoubtedly this finding has potential value, but it should be re-investigated.

4. It is recommended that the present study be used as a basis for a continuing longitudional study, by retesting the complete seven year sample during June and July, 1966. The limitations of the present cross-sectional study should be kept in mind during interpretation.

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A P P E N D I X

Computation of the Mean

$$\bar{X} = \frac{\Sigma X}{n}$$

(25:40)

Where:
X = Mean
n = No. of observations
X = value of observation

Computation of Variance and Standard Deviation:

$$S^2 = \frac{\Sigma x^2}{n-1}$$

(25:53)

Where:
S^2 = variance
n = No. of observations
X = value of observation
S = standard deviation

$$S = \sqrt{\frac{\Sigma (X-\bar{X})^2}{n-1}}$$

Test-Retest Reliability Coefficients:

$$S_t^2 = \frac{\Sigma xy}{n} - \left(\frac{\Sigma x}{n}\right)\left(\frac{\Sigma y}{n}\right)$$

Where:
S_t^2 = covariance of x and y
Σx = sum of trial one
Σy = sum of trial two
n = number of observations

$$S^2_{total} = \frac{S_x^2 + S_y^2}{2}$$

Where:
S^2_{total} = total variance
S_x^2 = variance of trial one
S_y^2 = variance of trial two

$$S_x^2 = \frac{\Sigma X^2}{n} - \left(\frac{\Sigma X}{n}\right)^2$$

$$S_y^2 = \frac{\Sigma y^2}{n} - \left(\frac{\Sigma y}{n}\right)^2$$

$$r_{XX} = \frac{S_t^2}{S^2_{total}}$$

Where:
r_{XX} = reliability coefficient

Analysis of Variance (the following calculations were used for Tables XXV and XXXVI)

Sum of Squares (within means) = $\left(\frac{\bar{X}_7^2}{n} + \frac{\bar{X}_8^2}{n} \ldots\ldots\ldots + \frac{\bar{X}_9^2}{n} \right)$

(25:143)

Sum of Squares (within conditions)

Where:

$\bar{X}_7^2$ = sum of seven year old means squared

n = number of observations

Sum of Squares (within conditions) = $\left[SS- \quad C \right] - \left[SS \text{ (within means)} \right]$

Where:

SS = sum of squares

Correction Term = $\frac{\text{Grand Sum}^2}{N}$

Where:

Gand Sum = sum of means
N = total number of subjects

Mean Square Variance = $\frac{SS}{df}$

F = $\frac{\text{Mean Square Variance (within Means)}}{\text{Mean Square Variance (within Conditions)}}$

Duncan's New Multiple Range Test:

The following procedure for the Duncan's New Multiple Range test (25:138) for right grip strength of male samples is given as an example. The procedure for use of Duncan's test for unequal sample numbers was that of Kramer (1956) (25:137). The explanation is for Table XXVI, which follows:

TABLE XXVI

DUNCAN'S NEW MULTIPLE RANGE TEST FOR GRIP STRENGTH RIGHT OF THE MALE SAMPLES

Age	7	8	9	10	11	12	13	14	15	Shortest Significant Range	
N	43	40	33	40	48	36	37	31	33		
Means	28.06	32.85	37.72	42.72	43.27	51.58	55.54	75.93	82.63		
										df 120	df ∞
7		4.79	9.66*	14.66*	15.21*	23.52*	27.48*	47.87*	54.57* R^2	42.8	42.11
8			4.87	9.87*	10.42*	18.73*	22.69*	43.08*	49.78* R^3	44.54	43.85
9				5.0	5.55	13.86*	17.82*	38.2[illegible]*	44.91* R^4	45.81	45.12
10					0.55	8.86*	12.82*	33.21*	39.91* R^5	46.74	45.43
11						8.31	12.27	32.66	39.36 R^6	47.43	46.74
12							3.96	25.35*	31.05* R^7	48.01	47.32
13								20.39*	27.09* R^8	48.59	47.78
14									6.70 R^9	48.94	48.24

* = difference in means statistically significant beyond the 0.01 level of confidence

Shortest Significant Range = $\sqrt{\text{Mean Square Variance (within Conditions)}}$ X

Significant Studentized Ranges for 1% Duncan Multiple Range Test

(25: Table X)

<u>Example Number 1:</u>

For the difference between fifteen and seven year old mean scores for male right grip strength, we find:

$$\bar{X}_{15} - \bar{X}_7 = 54.57\left(\sqrt{\frac{2(43\quad(33)}{76}}\right) > R_9$$

Where:

R_9 = shortest significant range for a mean difference through nine age ranges (df = 332)

and......
$$= 54.57\left(\sqrt{\frac{2838}{76}}\right)$$

= 54.57 (6.11)

=<u>333.42</u> Therefore; since 333.42 => R_9, a statistically significant difference (α=0.01) is found between fifteen year and seven year ages for male right grip strength.

Example Number 2:

For the difference between nine and eight year old mean scores for male right grip strength, we find:

$$X_9 - X_8 = 4.87\left(\sqrt{\frac{2(33)\quad(40)}{73}}\right) > R_2$$

Where:
R_2 = shortest significant range for a mean difference (α=0.01) through two age ranges(df=332)

and......

$$= 4.87\left(\sqrt{\frac{2640}{73}}\right)$$

$$= 4.87\ (6.0133)$$

$$= \underline{29.28}$$

Therefore; since 29.28 = $< R_2$ a significant difference (α=0.01) is not found between nine year and eight year ages for male right grip strength.

t Test

a) Test for Homogeneity or Heterogeneity

$$F = \frac{S_1^2}{S_s^2}$$

(25:106-07)

Where:
S_1^2 = largest mean variance
S_s^2 = smallest mean variance

b) t Test if variance Homogeneous (for heterogeneity b) and c)

$$S_{\bar{X}1} - \bar{X}_2 = \sqrt{\frac{S_x^2}{n} + \frac{S_y^2}{n}}$$

Where:
N = number of observations

and......

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{X_1} - X_2}$$

c) t Test if Variance Heterogeneous (i.e. the t as derived in b) is adjusted by Formula 8.2 (25:107)

$$t_{.01} = \frac{t_1 \frac{S_1^2}{n_1} + t_2 \frac{S_2^2}{n_2}}{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$$

Where:

t_1 = t value from Table V with n-1 df

t_2 = t value from Table V with n_2-1 df

Zero Order Correlations

$$r = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}} \quad (25:77)$$

Where:

x = variable one of the correlation
y = variable two of the correlation
r = reliability coefficient

t Test of the Hypothesis of Zero Correlation

$$t = \frac{r \sqrt{n-2}}{\sqrt{1-r^2}}$$

Where:

n = number of observations

and......

$$r = \sqrt{\frac{t^2}{n-2 + t^2}} \quad (25:78)$$

Percentile Norms

$$\text{Observation Number} = \frac{P\ (n+1)}{100}$$

HANDEDNESS OF THE SAMPLES TESTED ON STRENGTH

PARAMETERS

Female Samples

	Number Right Handed	Number Left Handed	% Right Handed
Age 7	33	3	92
Age 8	41	2	95
Age 9	41	4	91
Age 10	46	0	100
Age 11	39	4	91
Age 12	35	6	85
Age 13	29	3	91
Age 14	25	7	78
Age 15	27	3	90
Total	316	32	91

* Handedness is the reported writing hand of the subject

Male Samples

	Number Right Handed	Number Left Handed	% Right Handed
Age 7	38	5	88
Age 8	37	3	93
Age 9	29	4	88
Age 10	32	8	80
Age 11	41	7	85
Age 12	32	4	89
Age 13	35	2	95
Age 14	27	4	87
Age 15	24	9	83
Total	295	46	87
Male-Female Total	611	78	89

SAMPLE SCHOOLS OF THE STRENGTH STUDY

LEVEL	NO.	SCHOOL
Elementary	1	Our Lady of Victories
	2	Virginia Park
	3	Newton
	4	Abbott
	5	Strathearn
Junior High School	6	Oliver
	7	Killarney
	8	St. Kevins
	9	St. Angeles
	10	Westminster
Senior High Schools	11	St. Josephs
	12	Queen Elizabeth
	13	O'Leary
	14	Ross Sheppard
	15	Austin O'Brien